Northern Resident Killer Whales of British Columbia: Photo-identification Catalogue and Population Status to 2010

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ABSTRACT

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Field studies of the life history and ecology of killer whale populations off Canada's Pacific coast have been conducted annually since 1973. These studies are based on the identification of individual whales from photographs of permanent, natural markings. In this report, we summarize abundance trends in the northern resident killer whale population between 1974 and 2010, and provide an updated photo-identification catalogue of individuals in this population, displayed in a matrilineal framework. At the conclusion of the 2010 field season, the population was composed of the 3 clans, 16 pods, and 35 matrilines, with 261 individuals alive (plus four missing and possibly dead). The population is currently more than twice its size in 1974, representing an average annual increase of 2.1%. Continued population monitoring by photo-identification is a key research activity in the recovery strategy for this Threatened population.

RÉSUMÉ

Ellis, G.M., Towers, J.R., and Ford, J.K.B. 2011. Northern resident killer whales of British Columbia: Photo-identification catalogue and population status to 2010. Can. Tech. Rep. Fish. Aquat. Sci. 2942: v + 71 p

Des études sur le terrain portant sur le cycle vital et l'écologie des populations d'épaulard au large de la côte pacifique du Canada ont été réalisées tous les ans depuis 1973. Ces études se fondent sur la photo-identification d'individus à l'aide de marques naturelles et permanentes. Dans le présent rapport, nous résumons les tendances de l'abondance de la population résidente du nord du Pacifique Nord-Est entre 1974 et 2010 et fournissons un catalogue de photo-identification à jour des individus de cette population, dans un cadre matrilinéaire. À la fin de la campagne sur le terrain de 2010, la population était composée de 3 clans, de 16 groupes et de 35 lignées maternelles, pour un total de 261 individus vivants (plus 4 absents, probablement morts). La population compte actuellement plus du double d'épaulards qu'en 1974, ce qui représente une augmentation annuelle moyenne de 2,1 %. La surveillance continue de la population par photo-identification est une activité de recherche clé du programme de rétablissement de cette population menacée.

1.0 INTRODUCTION

Killer whales off the Pacific coast of Canada were among the first cetaceans found to be individually recognizable from photographs of natural markings. The use of individual photo-identification to study killer whale populations in British Columbia began in 1973 and continues to the present (Bigg et al. 1976, 1987; Bigg 1982; Ford et al. 1994, 2000; Ellis et al. 2007, 2008). Data collected using this method have been fundamental to the description of killer whale populations in the region and assessments of their abundance, life history traits, and social organization (Bigg 1982; Bigg et al. 1990; Olesiuk et al. 1990, 2005; Ford and Ellis 1999; Ford et al. 2007). The technique has also facilitated a wide range of studies on the species' biology, including behaviour (e.g., Jacobsen 1986; Morton 1990), acoustics (Ford 1991; Barrett-Lennard et al. 1996), foraging ecology (Nichol and Shackleton 1996; Ford et al. 1998, 2010a, 2010b; Ford and Ellis 2006) and genetics (Barrett-Lennard 2000).

Three separate forms, or lineages, of killer whales have been found to share coastal waters off the Pacific coast of Canada – residents, transients, and offshores. These lineages do not mix despite living in the same habitats, and as a result they are reproductively isolated and genetically distinct. Each lineage is ecologically specialized on different prey resources. Resident killer whales feed on fish and some squid, with a strong preference for salmon, especially Chinook. Transient killer whales prey on marine mammals and occasionally seabirds, and offshore killer whales feed on sharks and other large fish species (Ford et al. 1998, 2011).

Resident killer whales in British Columbia are represented by two distinct populations, northern and southern, which have overlapping ranges but do not intermingle. The northern resident population, which is the subject of this report, ranges between southern Washington State and southeastern Alaska (Dahlheim et al. 1997; Ford et al. 2000). Within this overall range, the great majority of encounters with northern resident killer whales have taken place in the coastal waters of British Columbia (Ford 2006). The smaller southern resident killer whale population ranges from central California to Haida Gwaii (formerly Queen Charlotte Islands), but is found most frequently during summer and fall in the transboundary waters of the Salish Sea, between Washington State and southern Vancouver Island.

Long-term studies of resident killer whales by means of individual photo-identification began in 1973 (Bigg et al. 1976). At that time, killer whales in British Columbia and Washington State were being commercially exploited by a live-capture fishery that began in 1964. Cropping from this fishery and mortality due to earlier intentional shootings (Bigg and Wolman 1975) resulted in a depleted population by the early 1970s. Preliminary results of the photo-identification studies by Bigg et al. (1976) showing fewer whales than previously thought, and public opposition to the captures, led to the end of the fishery in 1976 (Ford 2011).

Annual censuses of resident killer whales in both British Columbia and Washington State have been undertaken each year since 1974, coordinated by researchers with the Pacific Biological Station (primarily northern residents) and the Center for Whale Research, Friday Harbor, WA (southern residents). Both resident populations showed a long-term positive growth trend between 1974 and the mid 1990s, increasing at average rates of 2.5 to 3% per annum (Bigg 1982; Olesiuk et al. 1990, 2005). Northern and southern resident populations both experienced sharp increases in mortality rates and a decline in abundance during the latter half of the 1990s and early 2000s, which coincided with a coast-wide decline in availability of their primary prey, Chinook salmon (Ford et al. 2005, 2010a). In 2001, the conservation status of killer whales off the west coast was assessed by COSEWIC, and the northern residents were designated as Threatened and southern residents as Endangered due to their small population sizes, low reproductive rate and the existence of a variety of anthropogenic threats (COSEWIC 2008; Fisheries and Oceans 2008). These populations were subsequently legally listed as such under Canada's Species at Risk Act (SARA), and the process of recovery strategy development and identification of Critical Habitat was initiated (Fisheries and Oceans 2008). Annual censusing of resident killer whales by photo-identification is recognized in the recovery strategy for resident killer whales in Canada as an integral component of on-going population monitoring.

Results of the annual photo-identification censuses of resident killer whales have been presented in various scientific reports as well as catalogues primarily intended for field researchers, the whale-watch community, and the interested public. Technical reports describing the population status and dynamics of resident killer whales include Bigg et al. (1976), Bigg (1982), Bigg et al. (1990), Balcomb et al. (1980, 1982), Olesiuk et al. (1990, 2005), and Ford et al. (2005, 2010b). Photo-identification catalogues for northern and southern resident populations were provided in Bigg et al. (1987), and Ford et al. (1994, 2000). Updated catalogues have been provided periodically for southern resident killer whales by the Center for Whale Research (www.whaleresearch.com) and for northern residents by the Cetacean Research Program, Pacific Biological Station (Ellis et al. 2007; see http://www.pac.dfo-mpo.gc.ca/science/species-especes/cetacean-cetaces/index-eng.htm).

In this report, we present a summary of the current population status of the northern resident killer whale population through 2010, and an updated photo-identification catalogue of individuals. This catalogue includes demographic and genealogical data for all members of the northern resident population, gathered from annual photo-identification population censuses and associated long-term visual monitoring respectively. It is intended to provide research colleagues, monitoring program personnel as well as professional and recreational marine wildlife viewers with a tool to facilitate their studies and enrich their observations.

2.0 MATERIALS AND METHODS

2.1 DATA COLLECTION

Photo-identification censuses of northern resident killer whales have been undertaken annually from 1973 to 2010. Prior to the late 1980s, these censuses were conducted in Johnstone and Queen Charlotte Straits off northeastern Vancouver Island. However, as the range of northern resident killer whales became better understood, the study area was expanded to include the central and north coasts of mainland British Columbia, the north coast of Haida Gwaii, the west coast of Vancouver Island and southeastern Alaska. Field surveys were most often undertaken from small vessels ranging in size from 5 to 10 metres. Whales were found by patrolling areas known to be frequented by northern residents, and scanning visually or monitoring acoustically with a hydrophone. Whales were often located with the assistance of sighting reports or acoustic detections relayed to us by colleagues, other mariners or members of the public via cell phone or VHF radio. Killer whales were also encountered during multi-species cetacean surveys aboard Canadian Coast Guard ships (Ford et al. 2010c). When killer whales were found and weather conditions allowed, a small vessel was deployed for the purposes of obtaining identification photographs.

When located, whales were approached carefully from the left side to a minimum distance of 20 metres[1] and photographs of the dorsal fin and saddle patch area of each animal were taken from a position perpendicular to the whales' direction of travel. During an encounter, whales were photographed using this standardized process until a high quality image was obtained of every animal present. Individual killer whales were recognized visually in the field, either from memory or with the assistance of previously compiled photo-identification catalogues (Bigg et al. 1987; Ford et al. 2000; Ellis et al. 2007). As resident killer whales live in highly stable matrilineal groups, once a group was identified as being present in an encounter, social associations facilitated recognition of poorly marked individuals in the field. The left side eyepatch areas of any new calves present were also photographed for identification purposes, as saddle patch pigmentation and dorsal fin shape may not become distinct until the second or third year of life. Personnel aboard the survey vessel usually consisted of both an experienced driver and a photographer.

From 1973 to 2007, 35-mm single lens reflex (SLR) film cameras were used to obtain identification photographs. Preferred telephoto lenses ranged in focal length from 180 to 300 mm (Bigg et al. 1986). Black and white film with an ISO rating of 1600 was most commonly used. Images were overexposed by up to 2-3 stops to brighten the area behind the dorsal fin and bring out detail in the saddle patch, especially in situations with severe back-lighting. The high ISO rating of the film allowed for this overexposure while still upholding a fast shutter speed and moderate depth of field in

[1] Close approaches to whales for photo-identification were authorized by a scientific licence from DFO in Canada and a permit from NOAA Fisheries when in US waters.

almost any daytime lighting condition. Shutter speeds were set to a minimum of 1/1000 of a second and corresponding f-stops were set somewhere between 4.0 and 16. Beginning in 2008, digital SLR cameras with lenses ranging in focal length from 200 to 400 mm were used to obtain identification photographs in much the same way that film equipment had been used previously. Large/fine jpegs were the selected image resolution and type. Shutter speeds, as with film cameras, were set to a minimum of 1/1000 of a second while ISO ratings were set between 400 and 1600 depending on lighting conditions. F-stop settings ranged from 2.8 to 13. Images were over exposed by as much as 1.3 f-stops (or EV) in severely backlit circumstances.

2.2 DATA ANALYSIS

Prior to 2008, film was processed upon return from the field and then filed chronologically. Each frame of film taken during an encounter was analyzed in the lab by placing negative strips under a transmitted-light dissecting microscope and recording the identities of each animal in each frame as well as respective photo ratings when necessary on a corresponding data sheet. The naming system used is described by Bigg (1982), Bigg et al. (1987, 1990) and Ford et al. (2000). Animals were considered dead if they had not been seen despite multiple encounters with their pod or matriline (see Appendix) over a field season (Olesiuk et al. 1990). Encounter details such as date, location, photographer and the names of all animals present were recorded in a digital database. The best high-quality photographs of each individual whale in the population were printed (5x7") and placed in a master catalogue easily accessed when conducting the frame by frame analysis for assistance in identifying animals that were either poorly marked or had changed in appearance.

With the switch to digital photography in 2008, digital photograph storage and analysis protocols similar to those used for the film portion of this long term dataset were developed. These techniques are described in detail by Towers et al. (in prep). To summarize, digital photographs were analyzed by one of two of the authors (GE or JT) in much the same way as photographs taken on film. Date, location, photographer, animal identities, photo rating as well as any comments were applied directly to the metadata of every frame shot during an encounter. All metadata were then exported into a spreadsheet similar to the data sheets used to record whale identities depicted in film frames. Encounters were filed chronologically and a master folder of high quality images of each animal in the population was created by extracting these images using metadata search techniques (Towers et al. in prep).

All photographic data in this report were selected using one of these two analysis methods concerning either film or digital. Only encounters in which animals were systematically photographed using these methods were analyzed. Such encounters took place exclusively during northern resident photo-identification census surveys. High quality images were edited and cropped using Adobe Photoshop® before being

imported into a catalogue framework that was created with Adobe InDesign® (see Appendix). Catalogue structure was developed to represent known matrilineal genealogical relationships inferred from long term observations of matriline and pod social organization (Bigg et al. 1987, 1990; Ford et al. 1994, 2000; Ford and Ellis 2002).

3.0 RESULTS AND DISCUSSION

Since 2000, small vessel field effort to locate and photo-identify northern resident killer whales typically amounted to 7000-10,000 km of distance travelled per year. An additional 35,000 km of effort was tallied during CCG ship surveys during 2002-2010. During the 11 field seasons from 2000 to 2010, we averaged 59 encounters per year with northern residents (range = 46-85). This is roughly consistent with the range in numbers of annual encounters (range = 25-80) described by Bigg (1982) for the years from 1973 to 1981. Approximately 5000 photo-identification images were analyzed annually during 2000-2010.

The distribution of encounters with northern residents during 2000-2010 is illustrated in Figure 1. Over half (55%) of the total encounters were made off eastern Vancouver Island, with substantial proportions taking place along the north and central mainland coast of British Columbia (30%) and Haida Gwaii (11%).

In 2010, the northern resident population was composed of three acoustic clans with a total of 16 pods and 35 matrilines (Table 1; Appendix). Although the majority of matrilines were censused each year, it was often not possible to locate some matrilines each field season. As a result, there was occasionally some uncertainty in the numbers of individuals alive in each year. Although most uncertainties were eliminated when these matrilines were eventually encountered and individuals were accounted for, if an animal died during a gap of one or more years in monitoring, its actual year of death was not known. This uncertainty was relatively minor at an average of 0.7% of the total population abundance over the time series (range = 0-2.3% per year).

The abundance trend of the northern resident population during 1974-2010 is shown in Figure 2. From the mid 1970s to mid 1990s, the population grew steadily at an average annual rate of 2.6%, from approximately 122 individuals in 1974 to 218 in 1997. The population then declined by about 7% during 1998-2001, a period that coincided with a significant reduction in the availability of the whales' primary prey, Chinook salmon (Ford et al. 2010a). Starting in 2002, the growth trend became positive once again, with the population increasing at an average rate of 3.1% per year during 2001-2010 (range = 1.3-8.6% per annum). At the end of the 2010 field season, there were 261 individuals alive (plus four missing and possibly dead), more than double the population size in 1974. This represents an average annual increase of 2.1% over the 36 year time series. It is interesting to note that the southern resident population experienced a similar decline during the late 1990s, and it has not shown significant recovery since then (Fig. 2).

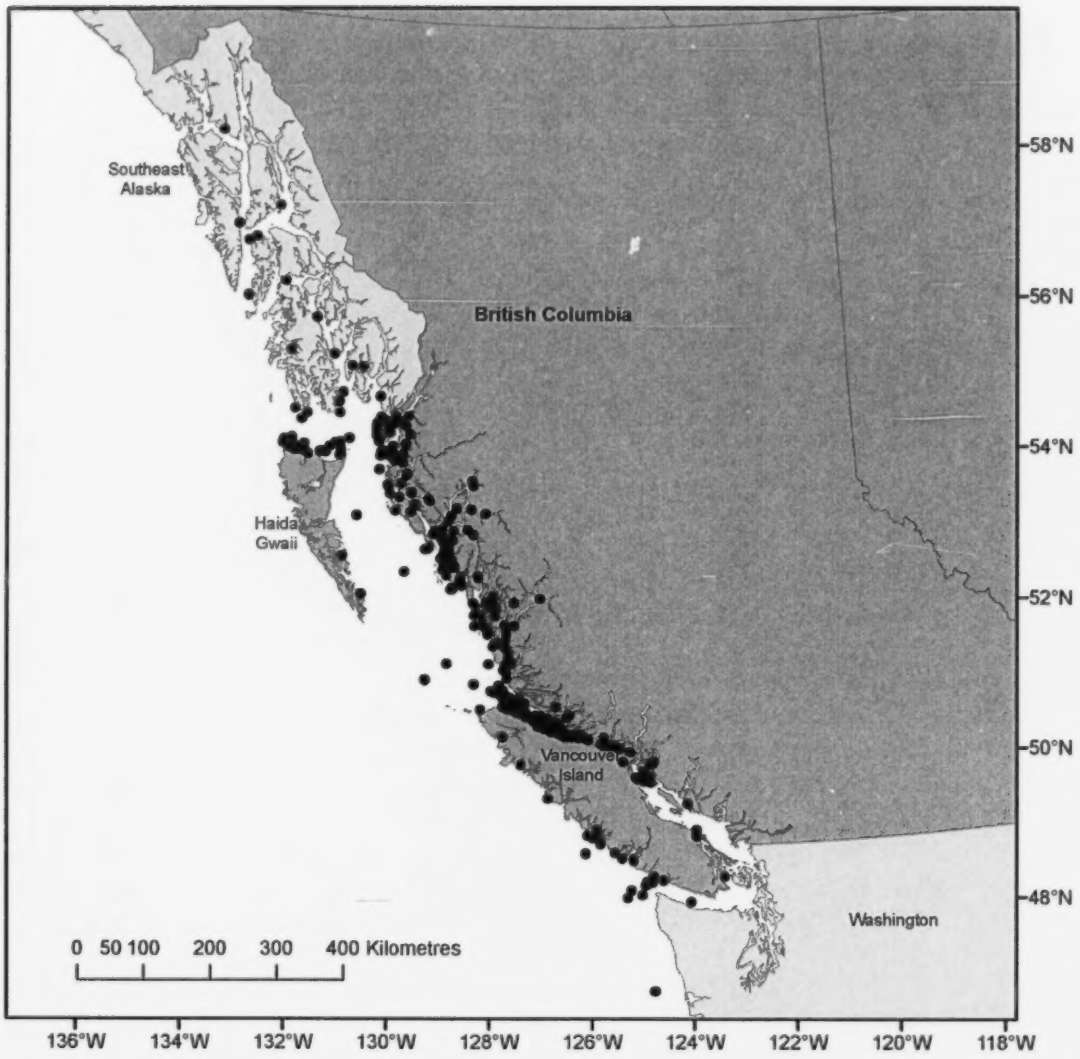

Figure 1. Locations of 617 encounters with northern resident killer whales, 2000-2010.

Table 1. Structure and size of the northern resident killer whale population in 2010. Matrilines not completely censused in 2010 are denoted with an asterisk, and number of animals missing and possibly dead are given in parentheses. Identification photos of each individual are shown in the Appendix.

Clan	Pod	Matriline	Size in 2010 (no. missing)
A	A1	A12	10
		A30	10
		A36	2
	A4	A11	9
		A24	7
	A5	A8	5
		A23	4
		A25	4
	B1	B7*	6 (1)
	C1	C6	9
		C10*	8 (1)
	D1	D7	7
		D11	5
	H1	H5	5
	I1	I19*	10 (1)
		I40	8
	I2	I22	3
	I18	I17	12
		I18*	12
G	G1	G3	16
		G16	3
		G17*	8 (1)
		G29	3
		G31	4
	G12	G2	9
		G8	1
		G27	6
	I11	I11	9
		I15	17
	I31	I31	10
R	R1	R2	2
		R5	25
		R13	2
		R17*	9
	W1	W3	1

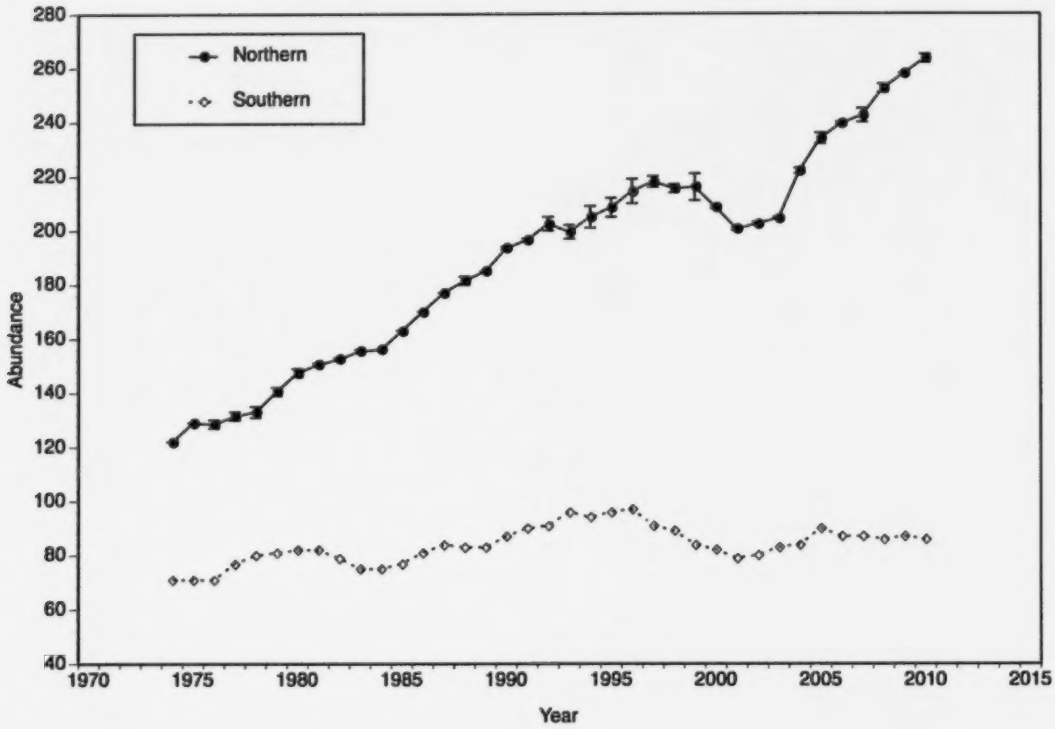

Figure 2. Abundance trends of northern and southern resident killer whale populations, 1974-2010. In years with uncertainty, the size is estimated as the mean of maximum and minimum possible population sizes, shown with error bars. Southern resident killer whale abundance data courtesy of the Center for Whale Research, Friday Harbor, WA.

All three northern resident clans experienced growth during 2001-2010, but at different rates (Figure 3). The A clan grew at the fastest average rate of 3.8% per annum, R clan at 2.7% per annum, and G clan at 2.4% per annum.

As our long-term photo-identification study of northern residents approaches its fifth decade, much of the uncertainty in demographic structure and genealogy that existed in the early stages of the study has diminished. In 2010, only 28 individuals in the current population were born before the study began 38 years ago. In other words, almost 90% of the population has been known since birth, and most of the remaining individuals since they were juveniles or young adults. Most genealogical linkages within the population are now certain, rather than possible or probable, and the unusual highly-stable matrilineal social structure of residents, initially described by Bigg et al. (1990), is confirmed with a further 20 years of data. Similarly, many of the life history parameters of residents, such as age and sex specific mortality rates, birth rates, etc., first

described by Olesiuk et al. (1990), have been further refined and adjusted with this longer time series (Olesiuk et al. 2005).

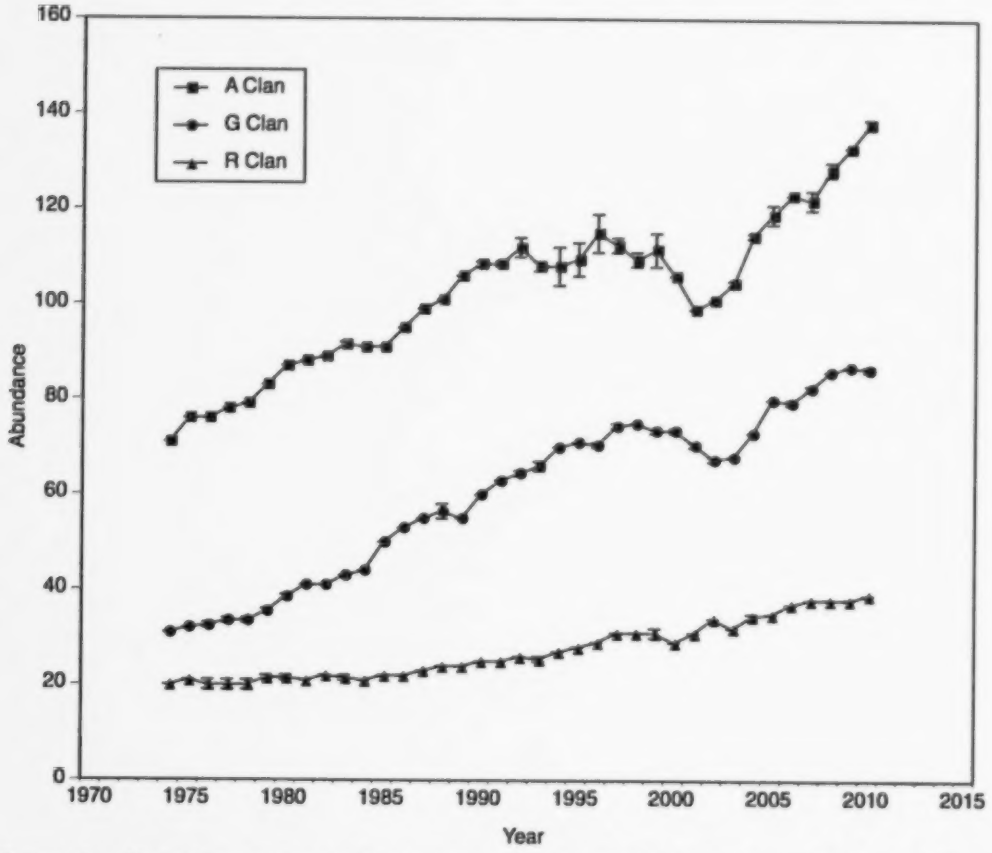

Figure 3. Abundance trends in the three northern resident clans, A, G, and R. Annual population estimates and error bar calculations as in Figure 2.

With each additional year of monitoring, our understanding of the population and social dynamics of these long-lived animals improves, as does our ability to detect subtle changes in these parameters that may result from anthropogenic threats. On-going photo-identification monitoring will continue to be a key component of recovery efforts focused on west-coast killer whales.

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6.0 REFERENCES

Balcomb, K. C. III, Boran, J. R. and Heimlich, S. L. 1982. Killer whales in greater Puget Sound. Report of the International Whaling Commission 32:681-685.

Balcomb, K. C. III, Boran, J. R., Osborne, R. W., and Haenel, N. J. 1980. Observations of killer whales (*Orcinus orca*) in greater Puget Sound, State of Washington. Report MM1300731-7, U.S. Marine Mammal Commission, Washington, D.C.

Barrett-Lennard, L.G. 2000. Population structure and mating patterns of killer whales (*Orcinus orca*) as revealed by DNA analysis. Ph.D. Thesis, University of British Columbia, Vancouver, BC. xi + 97 p.

Barrett-Lennard, L.G., J.K.B. Ford and K. Heise. 1996. The mixed blessing of echolocation: Differences in sonar use by fish-eating and mammal-eating killer whales. Anim. Behav. 51: 553-565.

Bigg, M.A. 1982. An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. Rep. Int. Whal. Commn. 32: 655-666.

Bigg, M.A., Ellis, G.M., and Balcomb, K.C. 1986. The photographic identification of individual cetaceans. Whalewatcher (J. Amer Cetacean Soc.) 20 (2):10-12.

Bigg, M.A., Ellis, G.M., Ford, J.K.B., and Balcomb, K.C. 1987. Killer Whales: A study of their identification, genealogy and natural history in British Columbia and Washington State. Phantom Press and Publishers, Nanaimo, BC. 79 p.

Bigg, M.A., MacAskie, I.B. and Ellis, G. 1976. Abundance and movements of killer whales off eastern and southern Vancouver Island with comments on management. Unpubl. Rep., Arctic Biological Station, Dept. of Fisheries and Environment, Ste Anne-de-Bellevue, Quebec.

Bigg, M.A., Olesiuk, P.F., Ellis, G.M., Ford, J.K.B., and Balcomb, K.C. III. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Rep. Int. Whal. Commn. Special Issue 12: 383-405.

Bigg, M.A. and Wolman, A.A. 1975. Live-capture killer whale (*Orcinus orca*) fishery, British Columbia and Washington, 1962-73. J. Fish Res. Bd Can. 32(7): 1213-1221

COSEWIC. 2008. COSEWIC assessment and update status report on the Killer Whale *Orcinus orca*, Southern Resident population, Northern Resident population, West Coast Transient population, Offshore population and Northwest Atlantic / Eastern Arctic population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 65 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Dahlheim, M., Ellifrit, D.K., and Swenson, J.D. 1997. Killer whales of southeast Alaska: a catalogue of photo-identified individuals. National Marine Mammal Laboratory, National Marine Fisheries Service, U.S. Department of Commerce, Seattle, Washington.

Ellis, G.M., Ford, J.K.B. and Towers, J.R., 2007. Northern Resident Killer Whales in British Columbia: Photo-Identification Catalogue 2007. Pacific Biological Station, Nanaimo.

Ellis, G.M., Towers, J.R. and Ford, J.K.B. 2008. Transient Killer Whales of British Columbia and Southeast Alaska: Photo-Identification Catalogue 2008. Pacific Biological Station, Nanaimo.

Fisheries and Oceans Canada. 2008. Recovery Strategy for the Northern and Southern Resident Killer Whales (*Orcinus orca*) in Canada. Species at Risk Act Recovery Strategy Series, Fisheries & Oceans Canada, Ottawa, ix + 81 pp.

Ford, J.K.B. 1991. Vocal traditions among resident killer whales (*Orcinus orca*) in coastal waters of British Columbia. Can. J. Zool. 69: 1454-1483.

Ford, J.K.B. 2006. An assessment of critical habitats of resident killer whales in waters off the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/072. iv + 34 p.

Ford, J.K.B. 2011. Killer whales of the Pacific northwest coast: From pest to paragon. Whalewatcher (J. Amer. Cetacean Soc.) 40 (1):15-23.

Ford, J.K.B., Abernethy, R.M., Phillips, A.V., Calambokidis, J., Ellis, G.M., and Nichol, L.M. 2010c. Distribution and relative abundance of cetaceans in western Canadian waters from ship surveys, 2002-2008. Can. Tech. Rep. Fish. Aquat. Sci. 2913: v + 51 p.

Ford, J.K.B., and Ellis, G.M. 2002. Reassessing the social organization of resident killer whales in British Columbia. Pages 72-75 in the Fourth International Orca Symposium and Workshop, September 23-28, 2002. CEBC-CNRS, France.

Ford, J.K.B., and Ellis, G.M. 2005. Prey selection and food sharing by fish-eating 'resident' killer whales (*Orcinus orca*) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/041. ii + 30 p.

Ford, J.K.B., and Ellis, G.M. 2006. Selective foraging by fish-eating killer whales Orcinus orca in British Columbia. Mar. Ecol. Prog. Ser. 316: 185-199.

Ford, J.K.B., Ellis, G.M. and Balcomb, K.C. 1994. Killer Whales: The natural history and genealogy of Orcinus orca in British Columbia and Washington State. UBC Press and University of Washington Press, Vancouver, BC and Seattle, WA. 102 p.

Ford, J.K.B., Ellis, G.M. and Balcomb, K.C. 2000. Killer Whales: The natural history and genealogy of Orcinus orca in British Columbia and Washington, Second edition. UBC Press and University of Washington Press, Vancouver, BC and Seattle, WA. 104 p.

Ford, J.K.B., Ellis, G.M., Barrett-Lennard, L.G., Morton, A.B., Palm, R.S., and Balcomb, K.C. III. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. Can. J. Zool. 76: 1456-1471.

Ford, J.K.B., Ellis, G.M. and Durban, J.W. 2007. An assessment of the potential for recovery of West Coast Transient Killer Whales using coastal waters of British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/088.

Ford, J.K.B., Ellis, G.M., Matkin, C.O., Wetklo, M.H., Barrett-Lennard, L.G., and Withler, R.E. 2011. Shark predation and tooth wear in a population of northeastern Pacific killer whales. Aquatic Biology 11:213-224.

Ford, J.K.B., Ellis, G.M. and Olesiuk., P.F. 2005. Linking prey and population dynamics: did food limitation cause recent declines of 'resident' killer whales (*Orcinus orca*) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/042.

Ford, J.K.B, Ellis, G.M., Olesiuk, P.F., and Balcomb, K.C. 2010a. Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? Biology Letters, 6:139-142. Published on-line before print September 15, 2009.

Ford, J.K.B., and Fisher, H.D. 1983. Group-specific dialects of killer whales (*Orcinus orca*) in British Columbia. pp. 129-61. In: R. Payne (ed.) Communications and Behaviour of whales. AAAS Selected Symposium 76. Boulder, Co 643pp

Ford, J.K.B, Wright, B.M., Ellis, G.M., and Candy, J.R. 2010b. Chinook salmon predation by resident killer whales: seasonal and regional selectivity, stock identity of prey, and consumption rates. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/101. iv + 43 p.

Morton, A.B. 1990. A quantitative comparison of the behavior of resident and transient forms of the killer whale off the central British Columbia coast. Rep. Int. Whaling Comm. Spec. Issue No. 12. pp. 245–248.

Nichol, L.M. and Shackleton, D.M. 1996. Seasonal movements and foraging behaviour of northern resident killer whales (*Orcinus orca*) in relation to the inshore distribution of salmon (*Oncorhynchus* spp.) in British Columbia. Can. J. Zool. 74: 983-991.

Olesiuk, P.F., Bigg, M.A., and Ellis, G.M. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Rep. Int. Whal. Commn. Special Issue 12: 209-242.

Olesiuk, P.F., Ellis, G.M. and Ford, J.K.B. 2005. Life history and population dynamics of northern resident killer whales (*Orcinus orca*) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/045. iv + 75 p.

Towers, J.R., Ford, J.K.B., and Ellis, G.M. 2011. Digital photo-identification dataset management and analysis. Testing protocols using a commercially available application. Can. Tech. Rep. Fish. Aquat. Sci., in preparation.

APPENDIX

PHOTO-IDENTIFICATION CATALOGUE OF NORTHERN RESIDENT KILLER WHALES

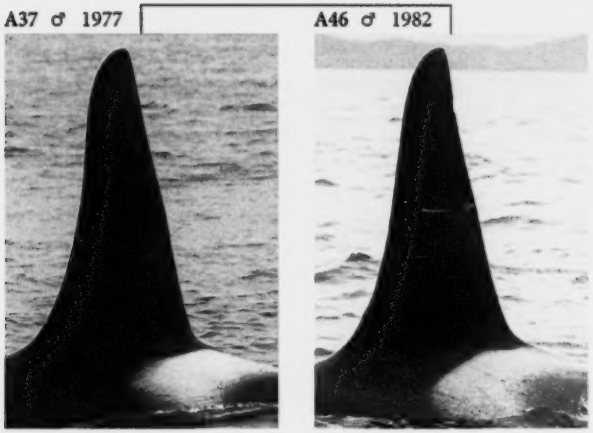
The following catalogue presents photo-identification images of northern resident killer whales, mostly collected during 2009 and 2010. They are arranged according to the matrilineal structure of the society. The basic social unit of residents is the *matriline,* which is a very stable kin group typically composed of an older female, her sons and daughters, and the offspring of her daughters. As the offspring of the daughters age, these new developing matrilines may spend more time apart from the older matriarch and her other offspring. Because the lifespan of females can reach 80 years and females have their first viable calf at about 14 years, a matriline may contain as many as five generations of maternally-related individuals, although 3-4 generations is typical.

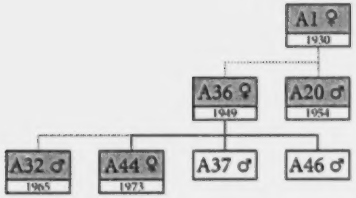
Matrilines that spend the majority of their time together are designated as *pods.* Pods are less stable than matrilines, and member matrilines may spend days or weeks apart. However, matrilines generally spend more time with others from their pod than with those from other pods. The next level of social structure above the resident pod is the *clan*, which includes pods that have related vocal dialects. Different clans have no calls in common, and sound distinctly different even to an untrained ear. Pods belonging to a clan are likely descendants of an ancestral pod and their acoustic similarities reflect this common heritage.

A key is provided in the catalogue to help interpret demographic and genealogical details. Lines linking mothers and offspring are solid if the relationship is positive. This includes individuals that have been documented since birth. Relationships of whales born before the study began in the early 1970s are either probable, indicated by a dashed line, or possible, indicated by a dotted line. The four whales that could not be confirmed to be alive in 2010 are indicated with an asterisk. In addition to photographs of living whales, a schematic diagram of each matriline and pod is provided, which includes animals that have died over the course of the study.

Photographs and demographic data presented in the following catalogue are provided to facilitate field studies and to enhance observations by the whale-watching public. Years of births and deaths often have varying levels of uncertainty and may be estimated. For this reason, these data are not appropriate for analyses of population dynamics. Researchers interested in undertaking such analyses are requested to contact the authors directly. Images and other data in this catalogue are not to be reproduced without the authors' permission.

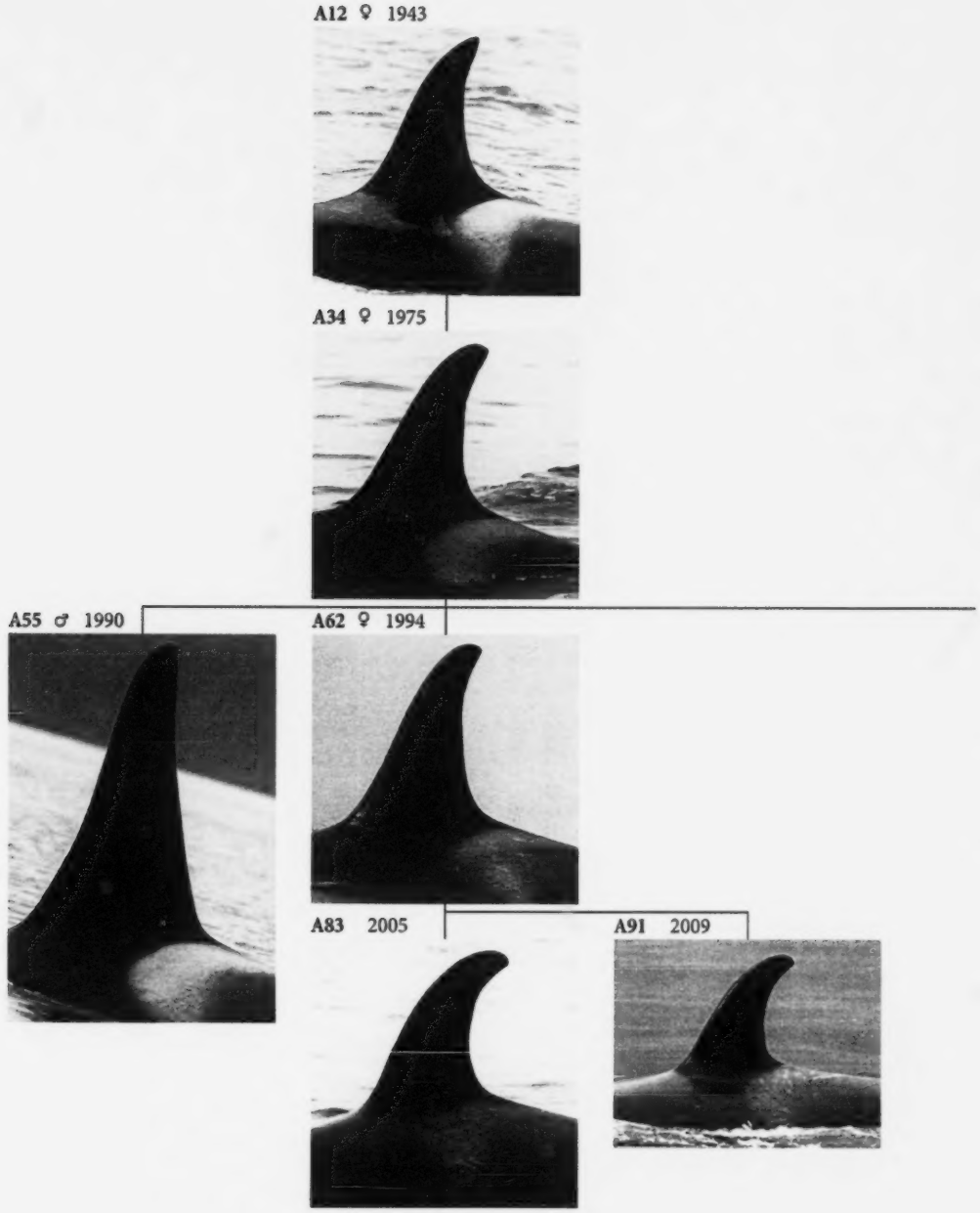
A1 Pod, A Clan
A36 Matriline





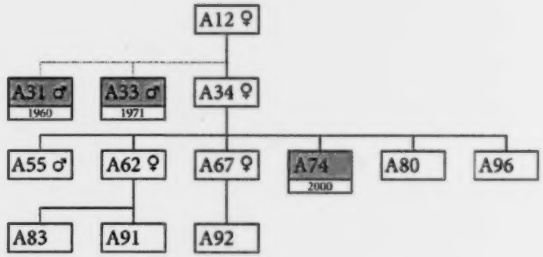
A1 Pod, A Clan
A12 Matriline

Since the death of A33 in 2009, A12 is often seen travelling with the A36 matriline.



A1 Pod, A Clan

A12 Matriline



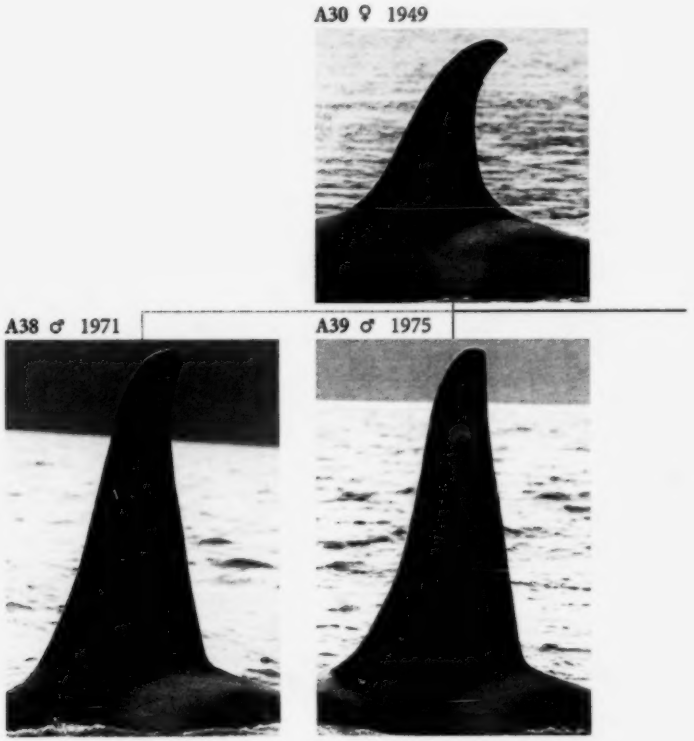
A67 ♀ 1997

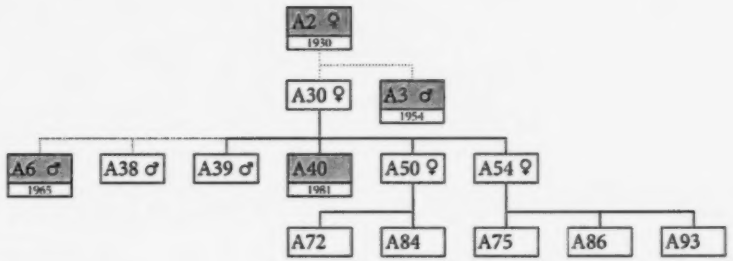
A80 2004

A96 2010

A92 2009

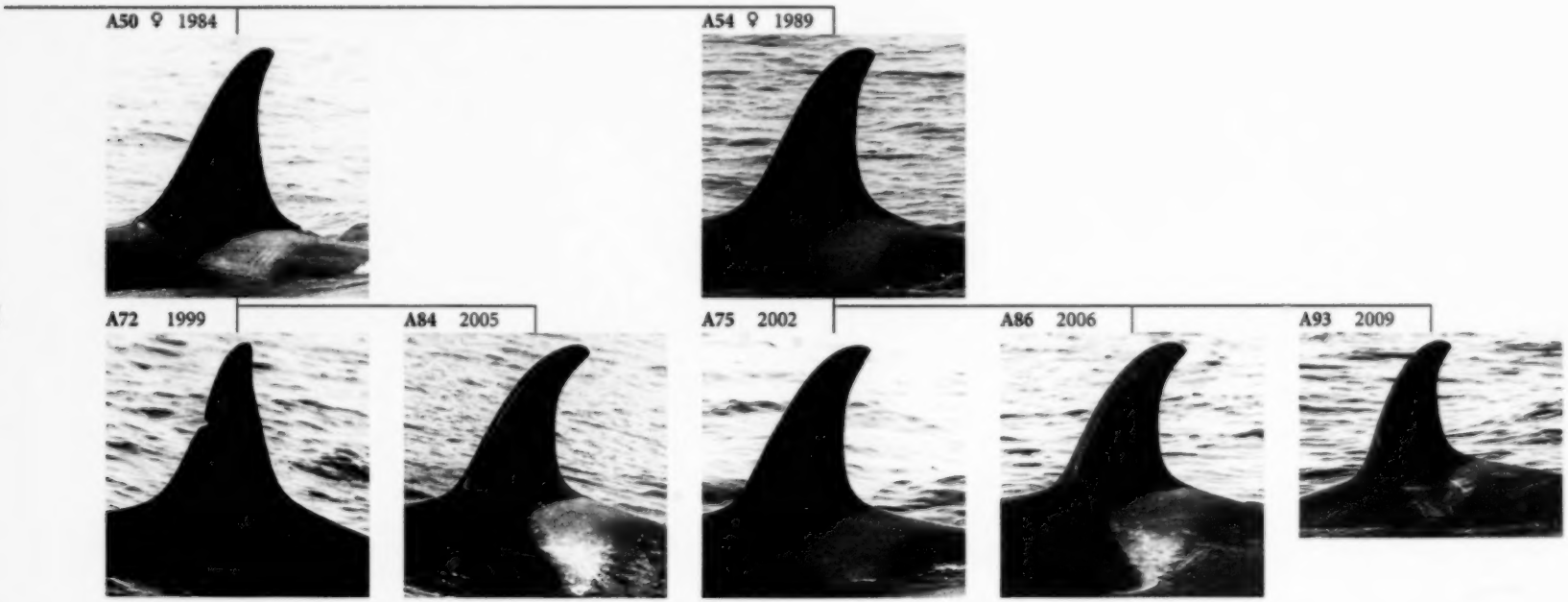
A1 Pod, A Clan
A30 Matriline



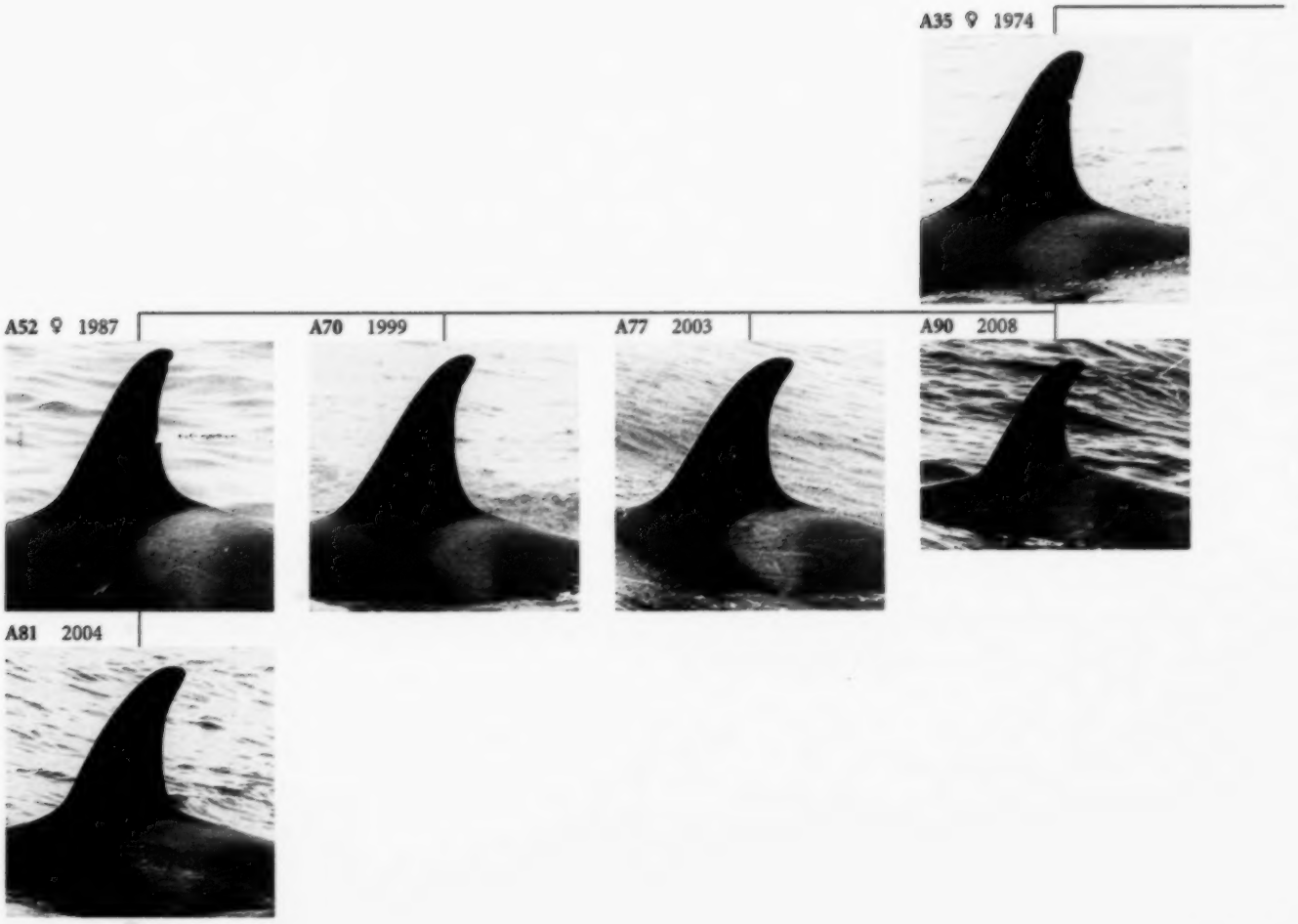


A1 Pod, A Clan

A30 Matriline



A4 Pod, A Clan
A11 Matriline

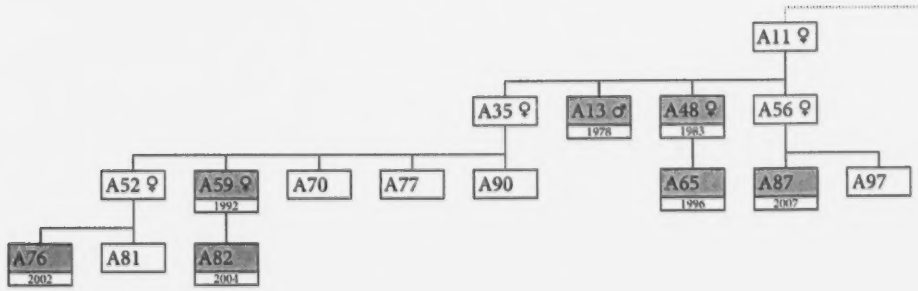


A4 Pod, A Clan
A11 Matriline

A11 ♀ 1959

A56 ♀ 1990

A97 2010



A4 Pod, A Clan
A24 Matriline

The orphan A73 (Springer) usually travels with the A11 or A24 matriline.

A24 ♀ 1967

A64 ♀ 1995

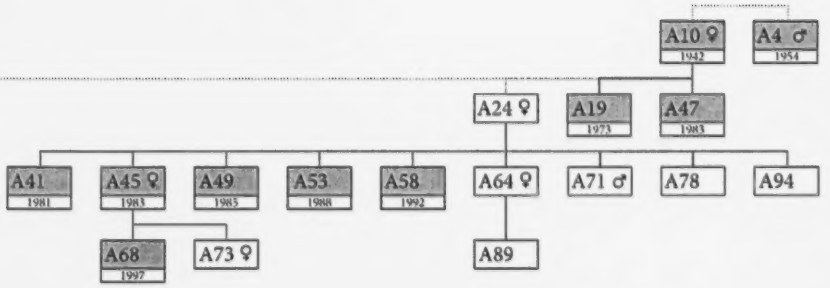
A71 ♂ 1999

A78 2003

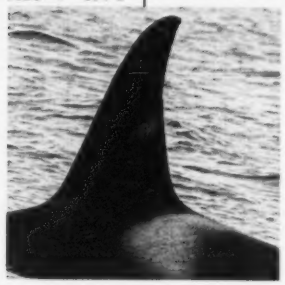
A94 2009

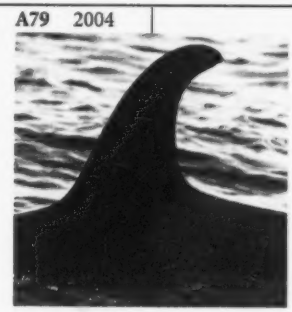
A73 ♀ 2000

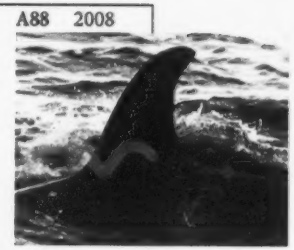
A89 2008

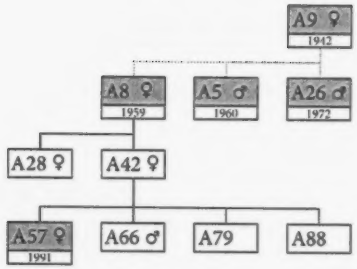


A5 Pod, A Clan
A8 Matriline



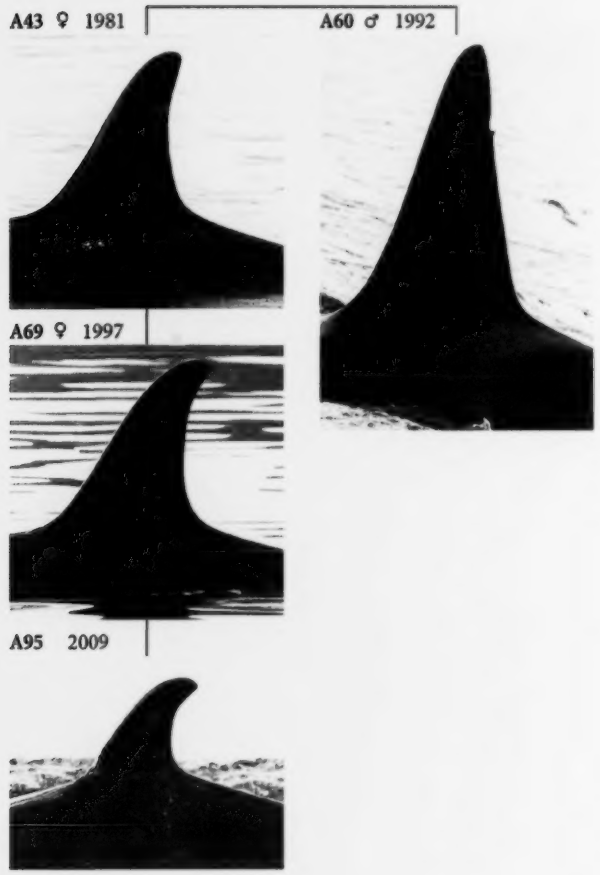


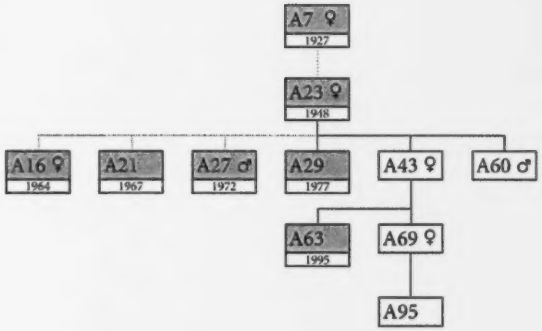




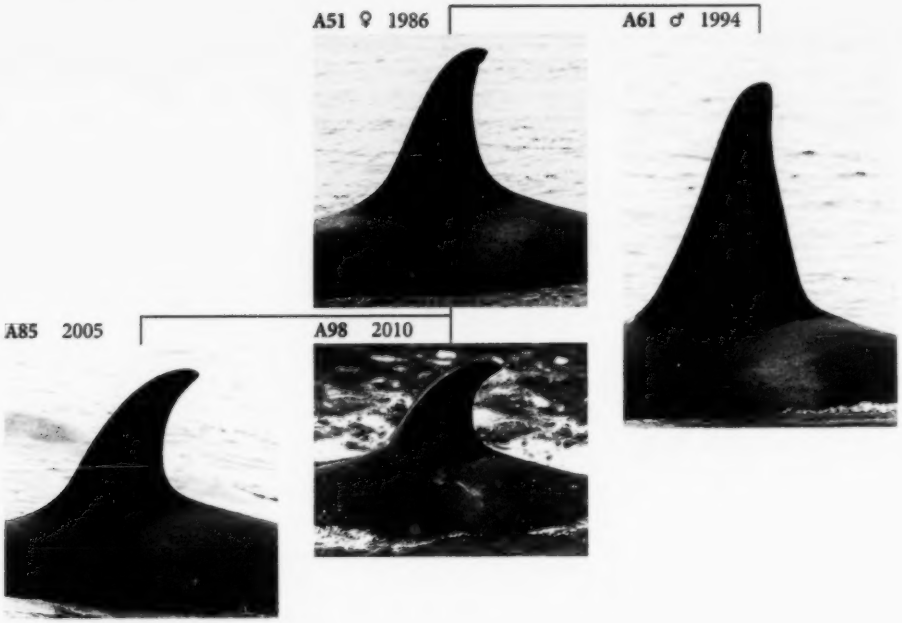
A5 Pod, A Clan

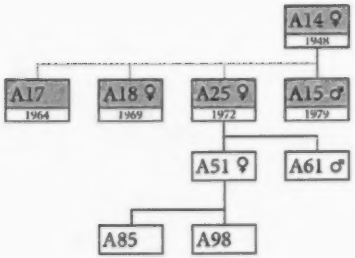
A23 Matriline





A5 Pod, A Clan
A25 Matriline





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CATALOGUE KEY

A12 ♀ Live whale with ID and sex

A1 ♀ 1930 Deceased whale with birth year

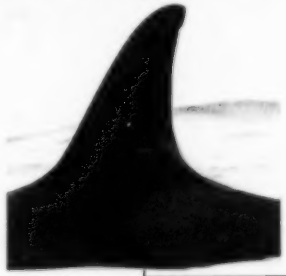
Positive Relationship

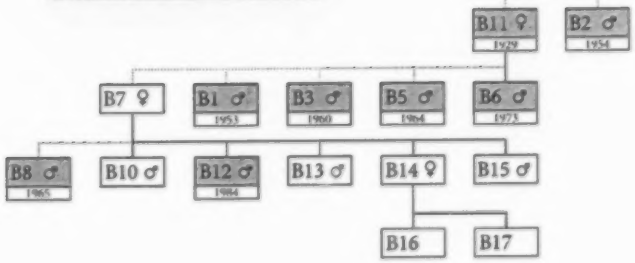
Probable Relationship

Possible Relationship

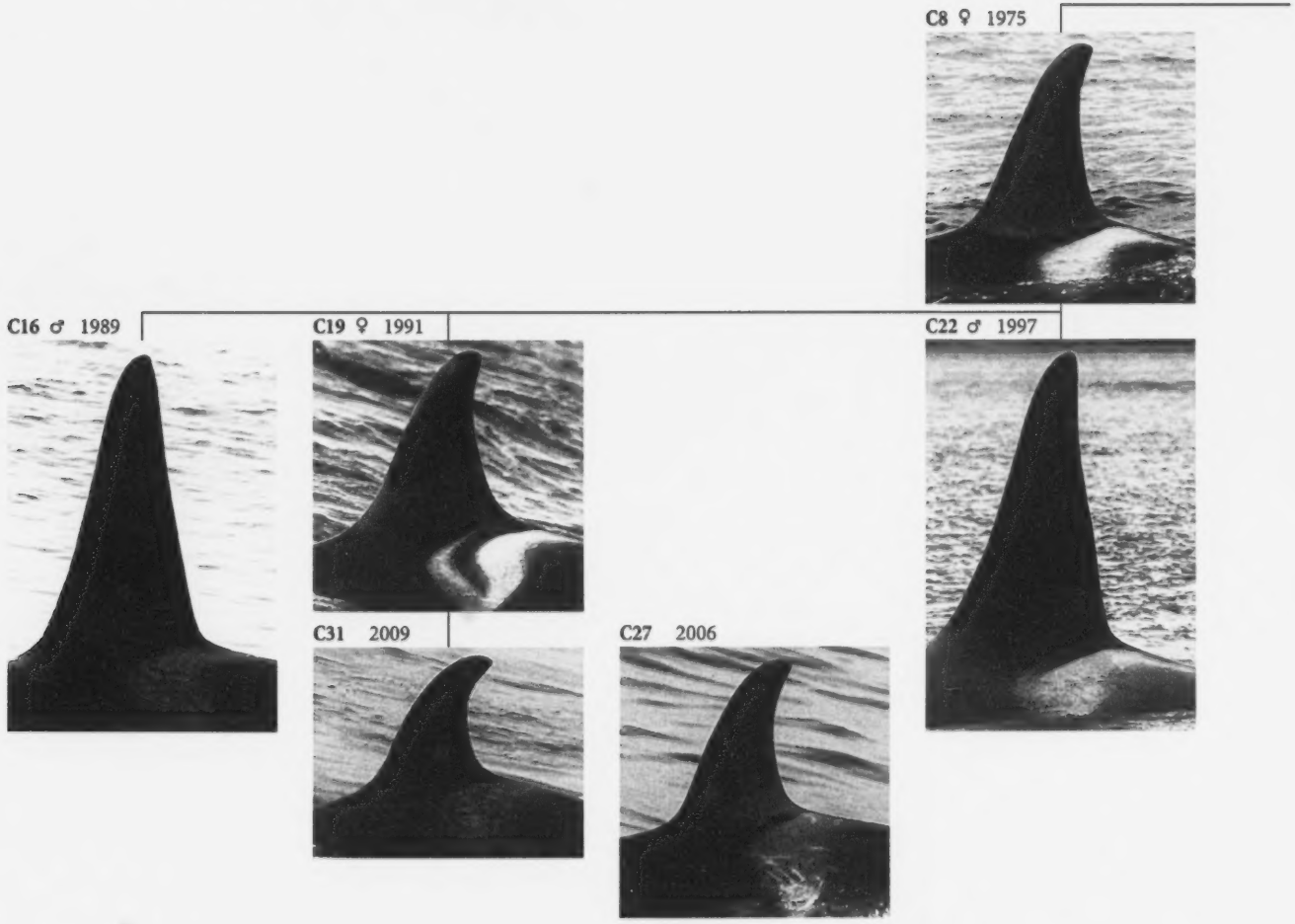
* Missing in 2010

B1 Pod, A Clan
B7 Matriline





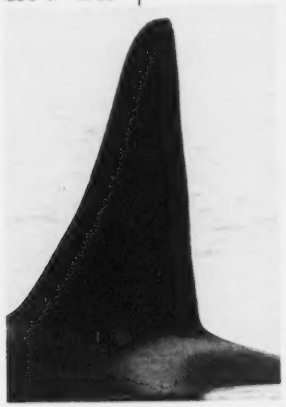
C1 Pod, A Clan
C6 Matriline



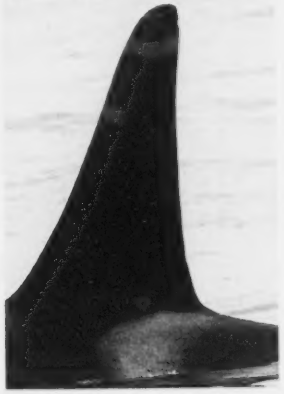
C1 Pod, A Clan
C6 Matriline

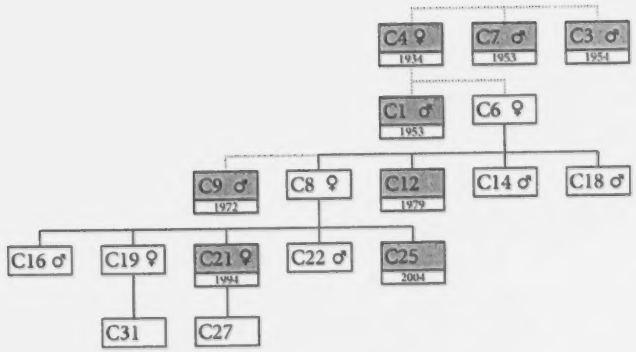
C6 ♀ 1956

C14 ♂ 1985

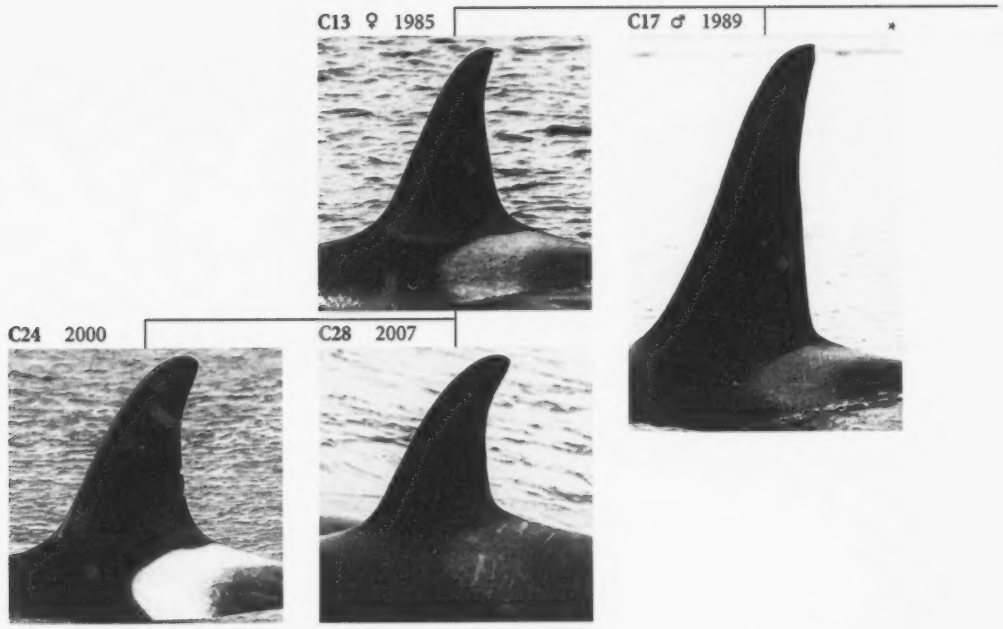


C18 ♂ 1991

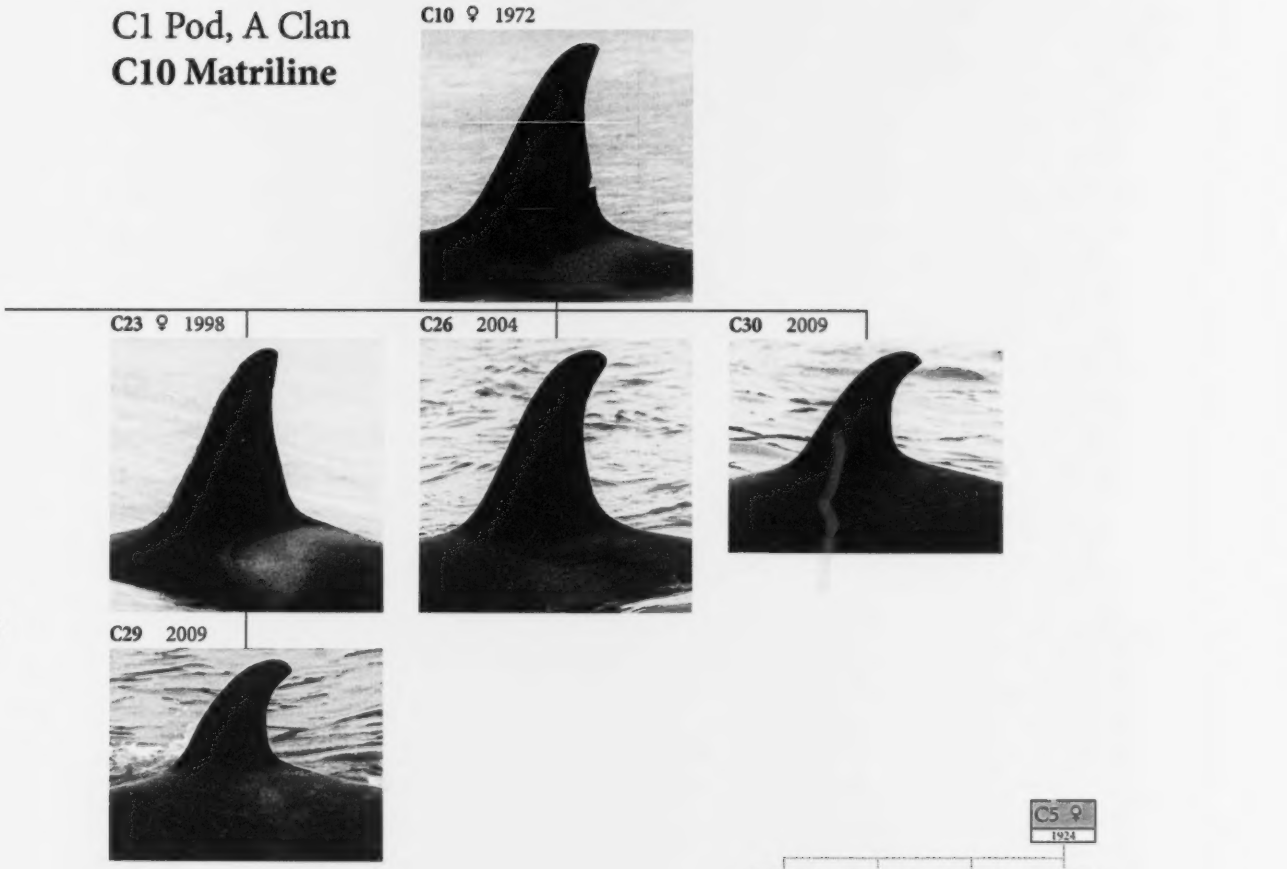


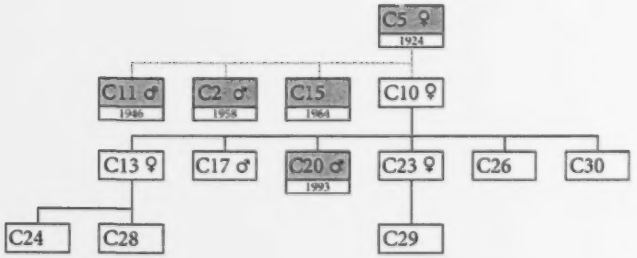


C1 Pod, A Clan
C10 Matriline



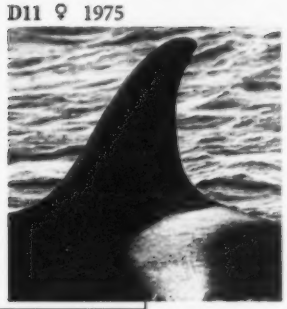
C1 Pod, A Clan
C10 Matriline

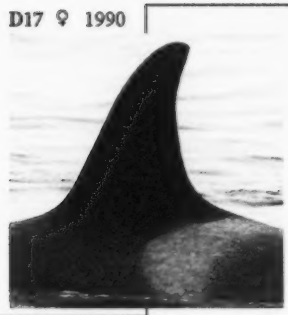


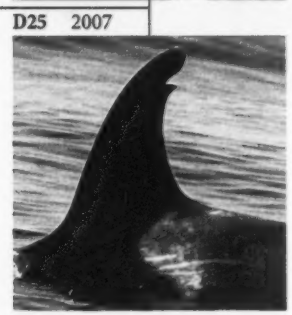


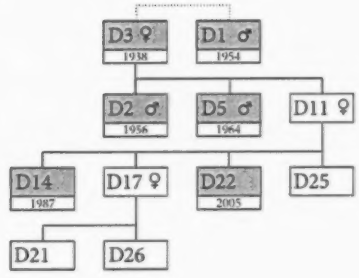
D1 Pod, A Clan

D11 Matriline









D1 Pod, A Clan
D7 Matriline

D9 ♀ 1972

D10 ♀ 1978

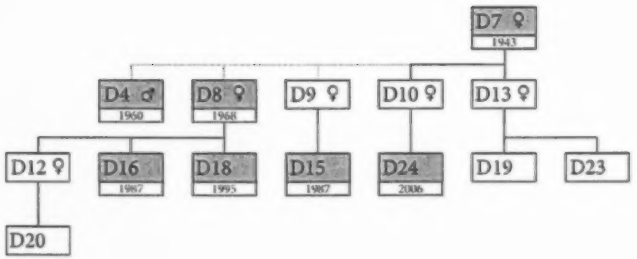
D13 ♀ 1984

D12 ♀ 1982

D19 1998

D23 2005

D20 1999



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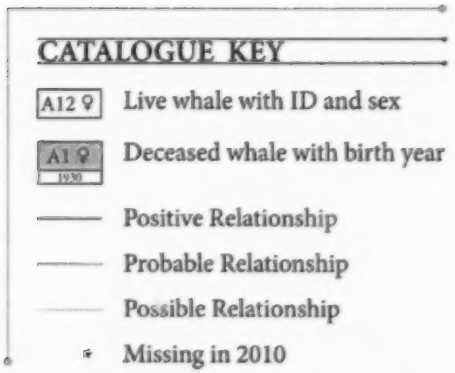
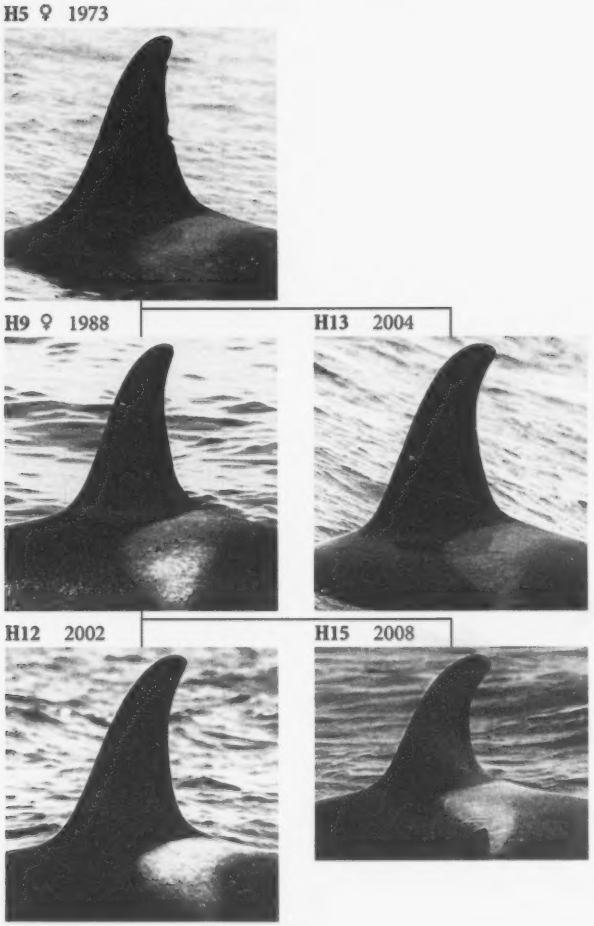
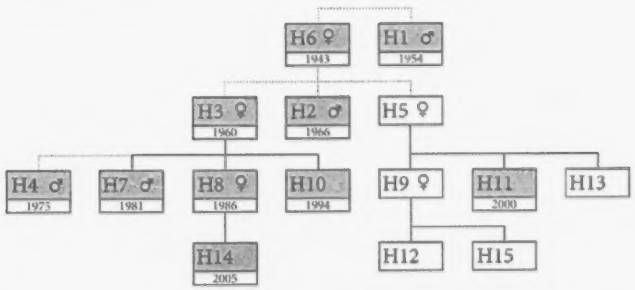


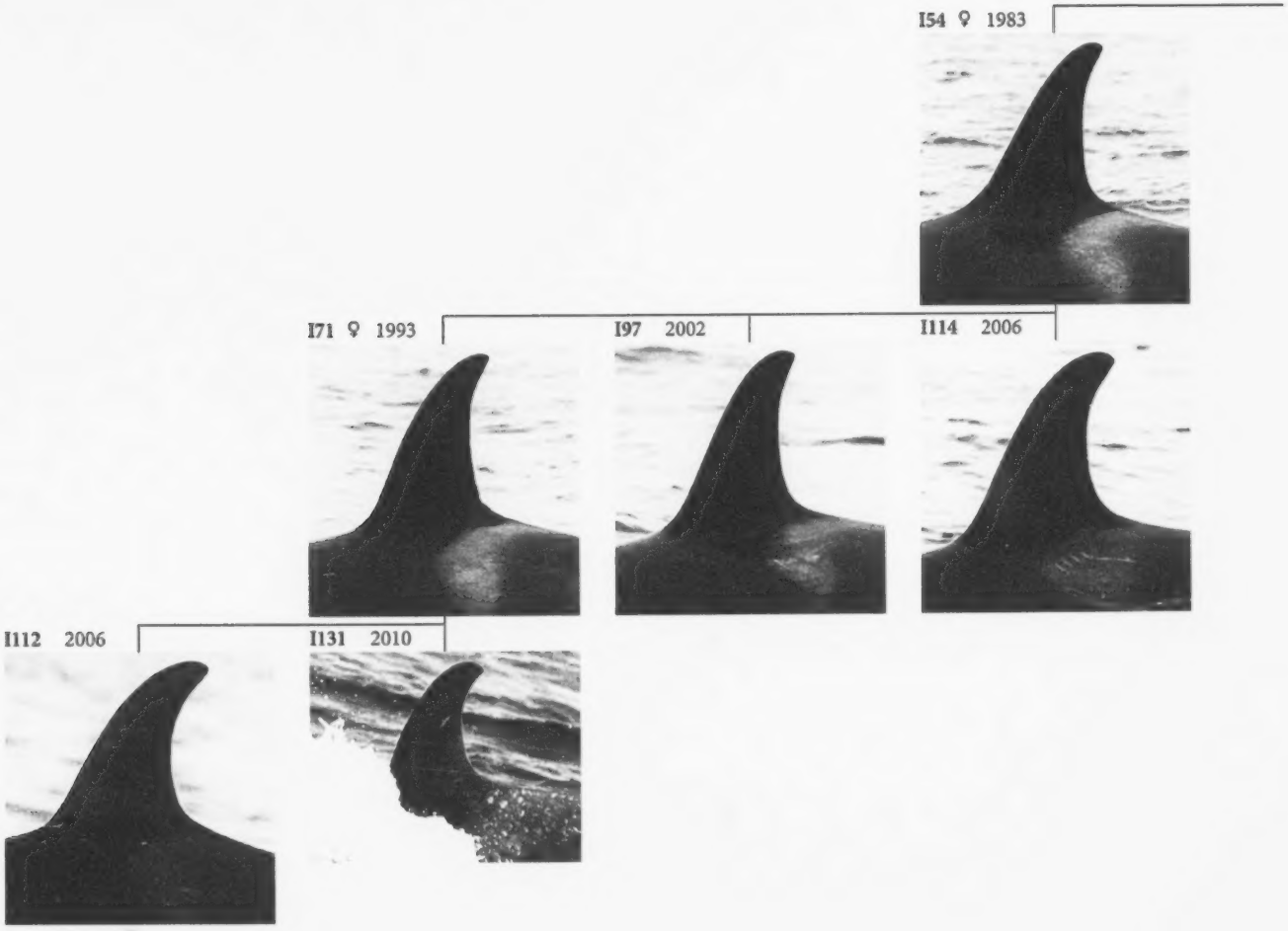
H1 Pod, A Clan
H5 Matriline



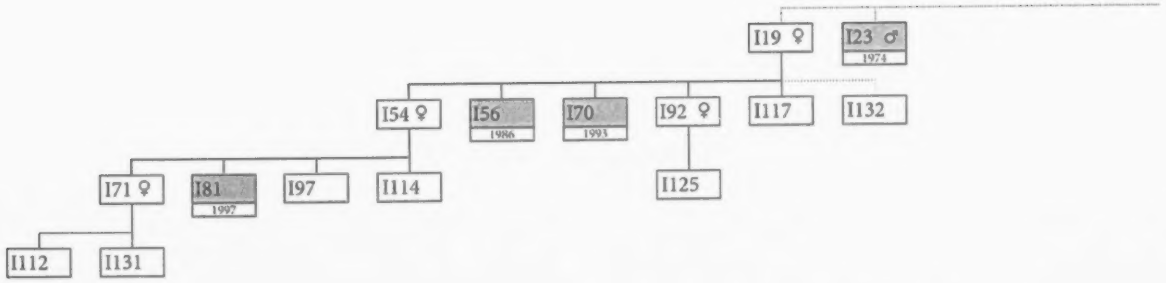


I1 Pod, A Clan

I19 Matriline



I1 Pod, A Clan
I19 Matriline



I1 Pod, A Clan
I40 Matriline

I40 ♀ 1980

I69 ♀ 1991

I82 ♀ 1994

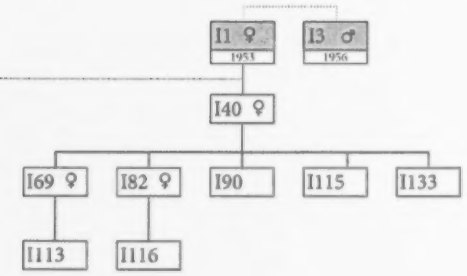
I90 1999

I115 2005

I133 2010

I113 2006

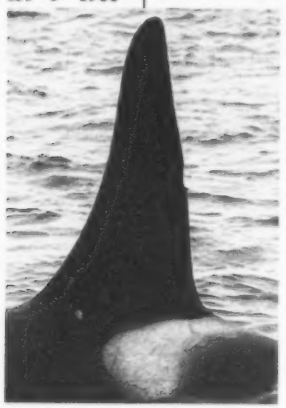
I116 2006



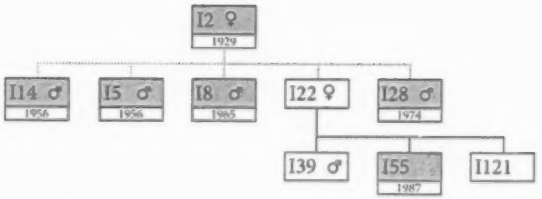
I2 Pod, A Clan
I22 Matriline

I22 ♀ 1966

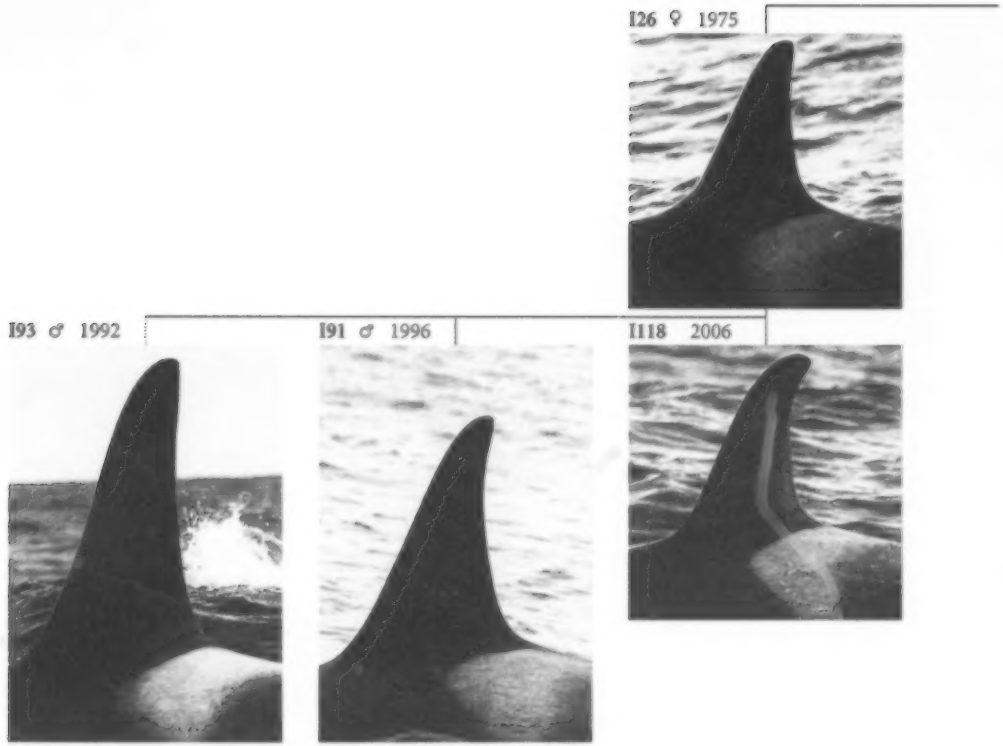
I39 ♂ 1980



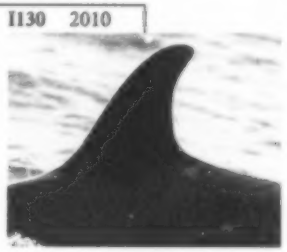
I121 2007

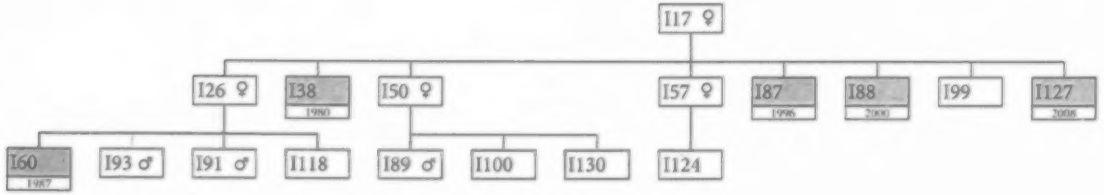


I18 Pod, A Clan
I17 Matriline

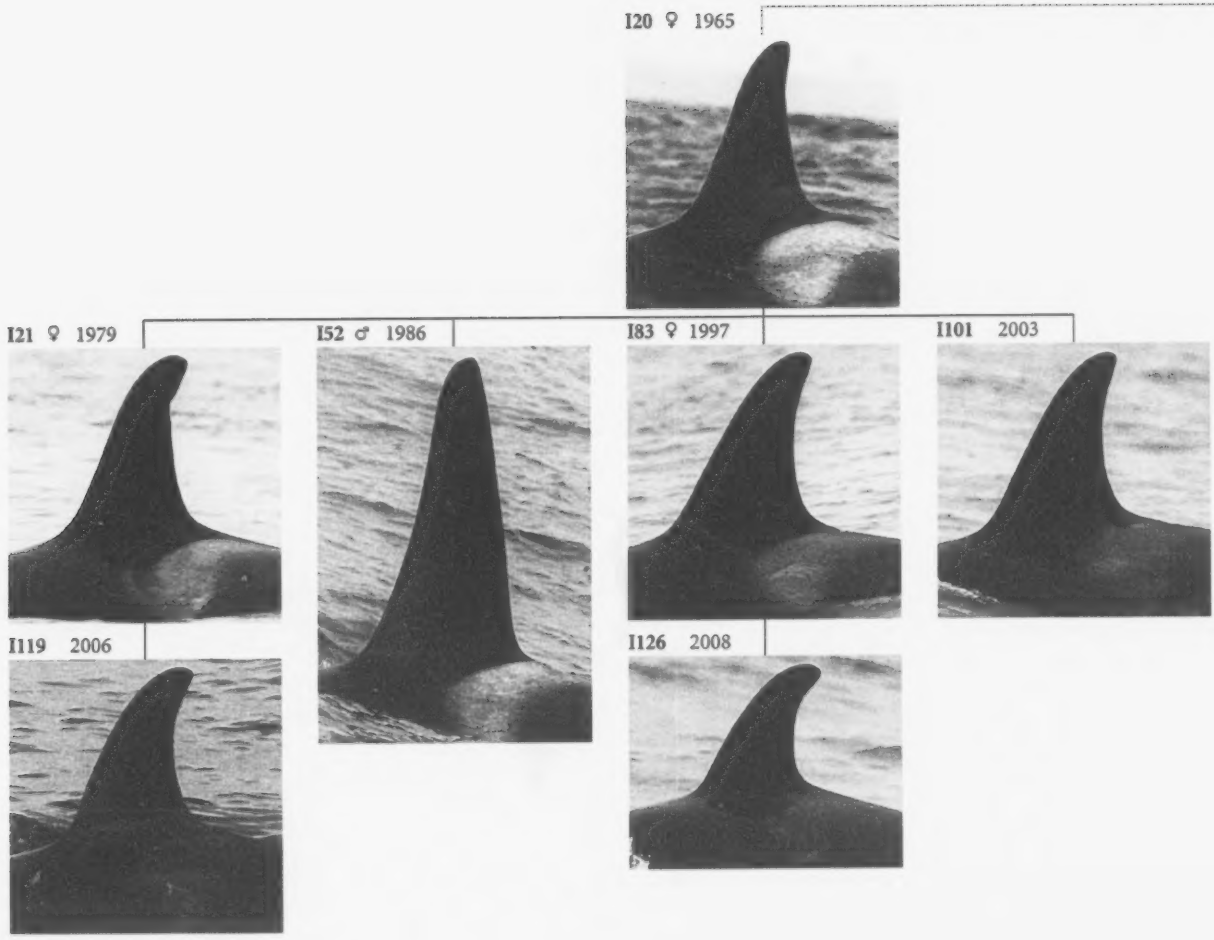


I18 Pod, A Clan
I17 Matriline





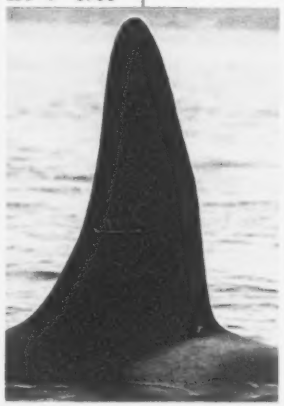
I18 Pod, A Clan
I18 Matriline



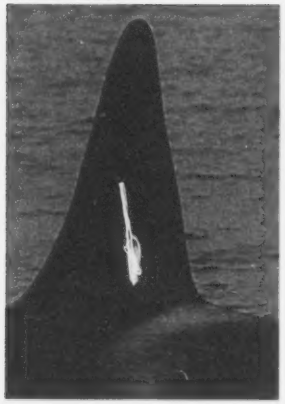
I18 Pod, A Clan
I18 Matriline

I24 ♀ 1980

I53 ♂ 1986

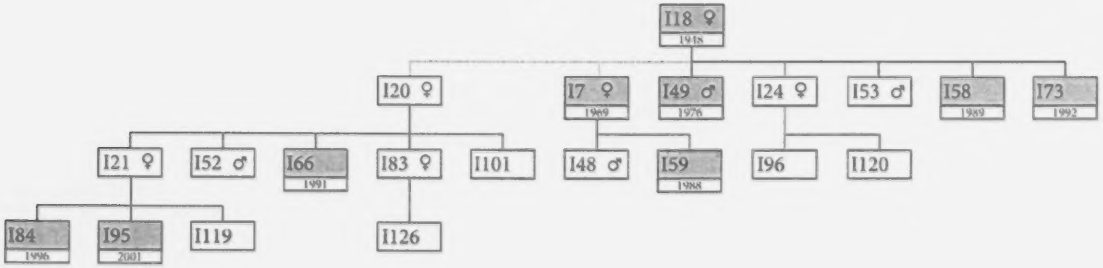


I48 ♂ 1983



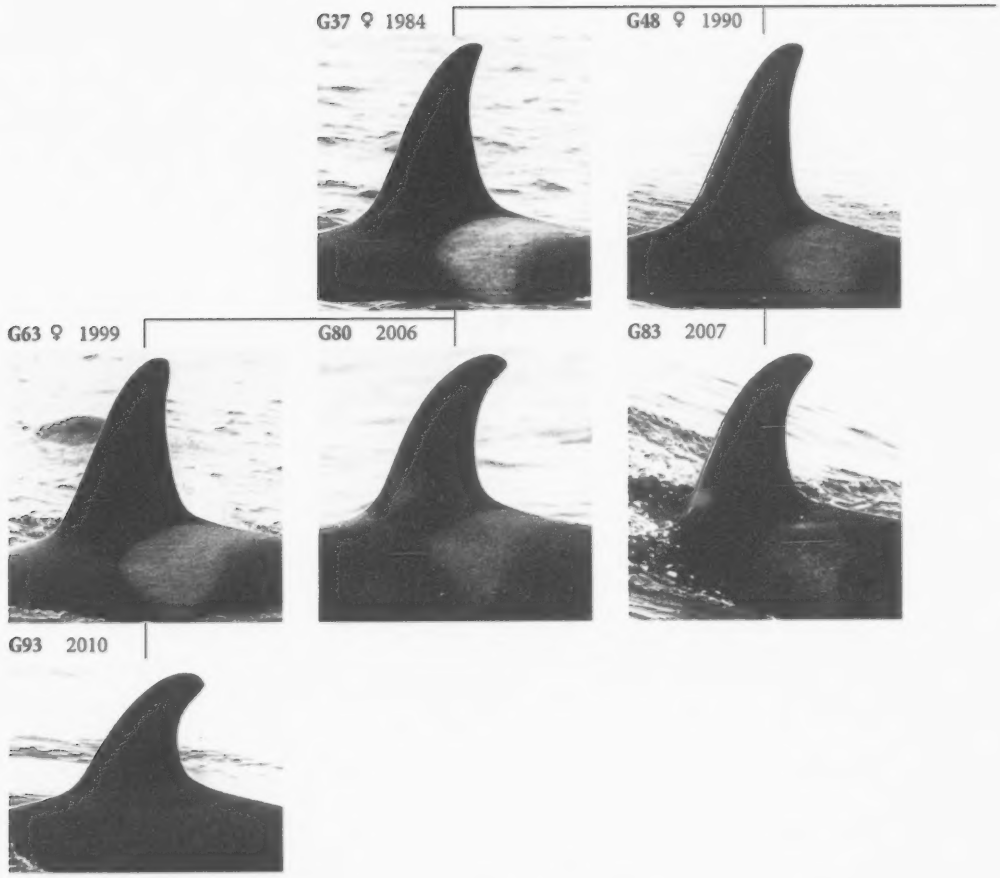
I96 2002

I120 2007

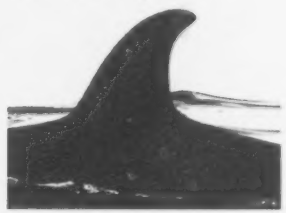


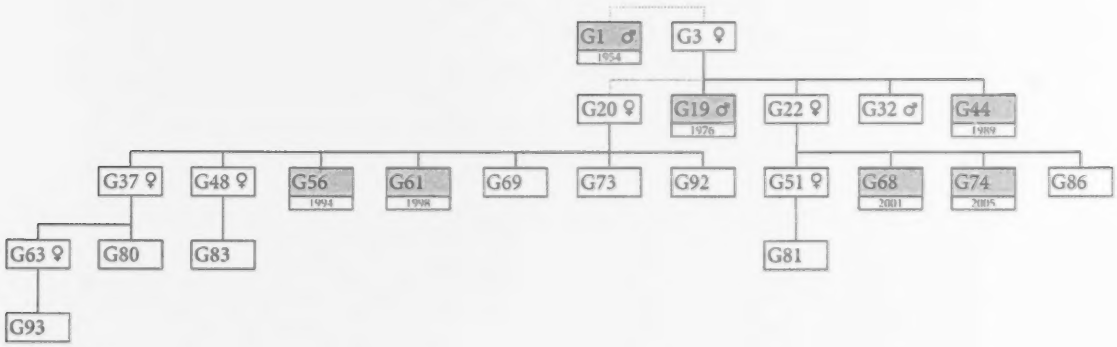
G1 Pod, G Clan

G3 Matriline



G1 Pod, G Clan
G3 Matriline

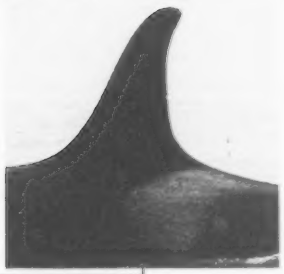




G1 Pod, G Clan

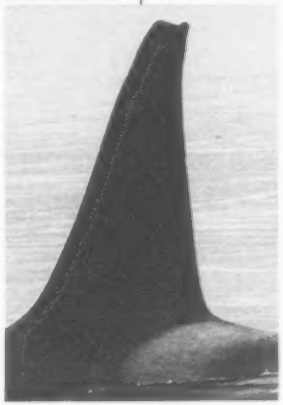
G3 Matriline

G3 ♀ 1957



G22 ♀ 1979

G32 ♂ 1982



G51 ♀ 1992

G86 2008

G81 2006

Photographs and demographic data presented in this catalogue are provided to facilitate field studies and to enhance observations by the whale-watching public. Years of births and deaths often have varying levels of uncertainty and may be estimated. For this reason, these data are not appropriate for analyses of population dynamics. Researchers interested in undertaking such analyses are requested to contact the authors directly. Images and other data in this catalogue are not to be reproduced without the authors' permission.

CATALOGUE KEY

Live whale with ID and sex

Deceased whale with birth year

Positive Relationship

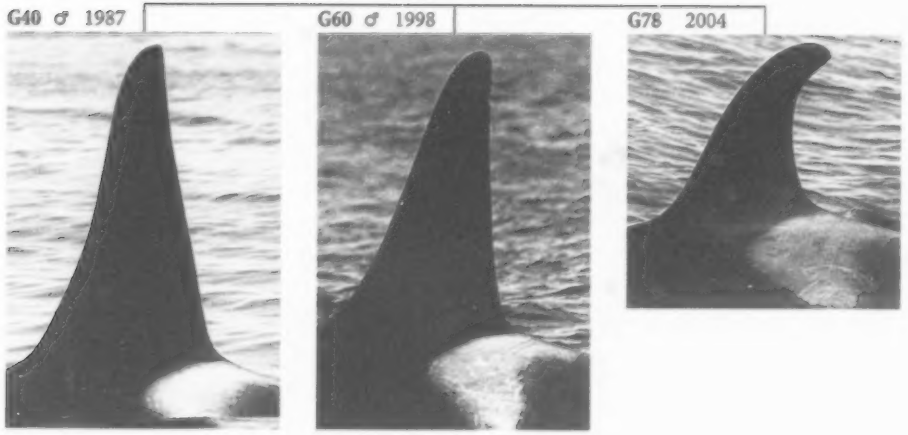
Probable Relationship

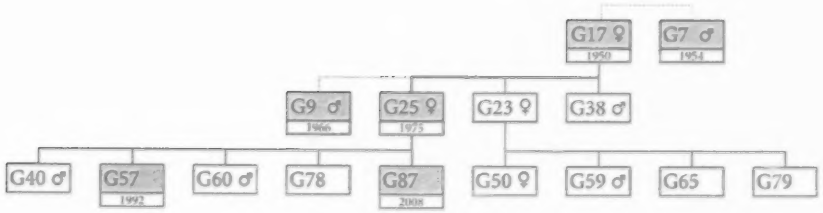
Possible Relationship

* Missing in 2010

G1 Pod, G Clan

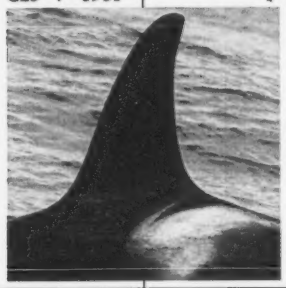
G17 Matriline





G1 Pod, G Clan
G17 Matriline

G23 ♀ 1981



G38 ♂ 1986

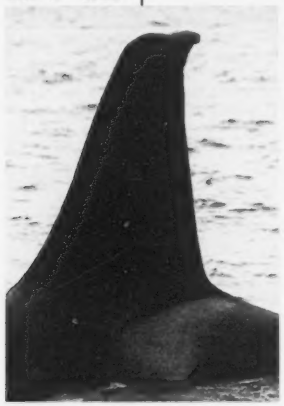
G50 ♀ 1991

G59 ♂ 1995

G65 2001

G79 2005

G1 Pod, G Clan
G16 Matriline


G39 ♂ 1986

G52 ♀ 1993

G94 2010

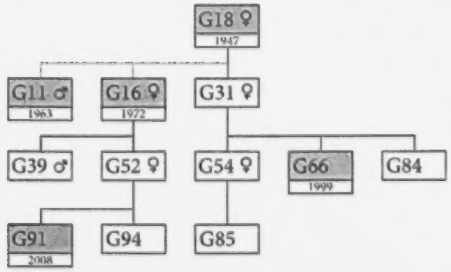
G1 Pod, G Clan
G31 Matriline

G31 ♀ 1981

G54 ♀ 1994

G84 2007

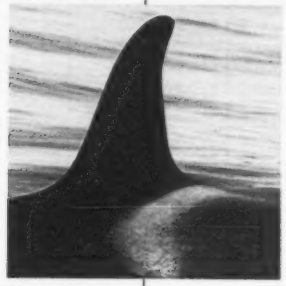
G85 2008



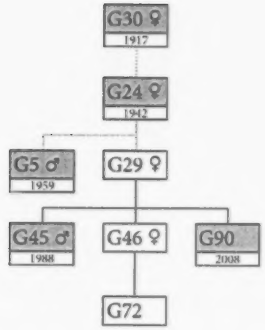
G1 Pod, G Clan
G29 Matriline

G29 ♀ 1971

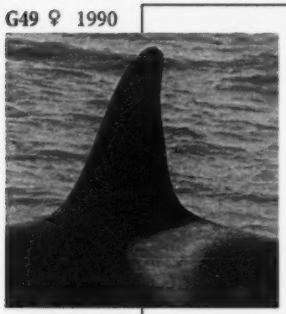
G46 ♀ 1991

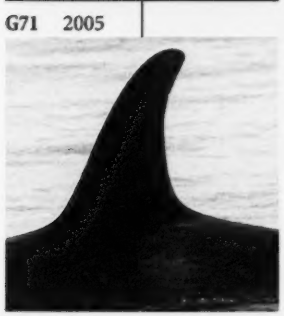


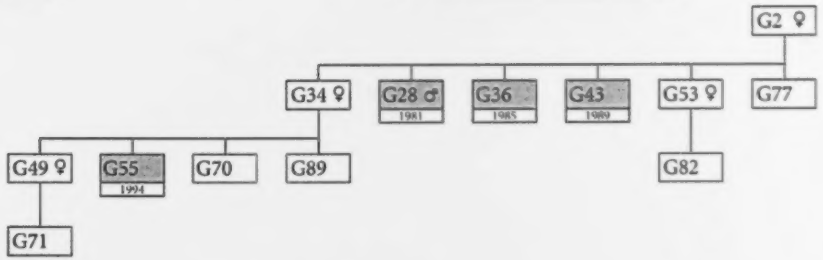
G72 2005



G12 Pod, G Clan
G2 Matriline







G12 Pod, G Clan
G8 Matriline

G12 Pod, G Clan
G27 Matriline

G27 ♀ 1974

G62 1999

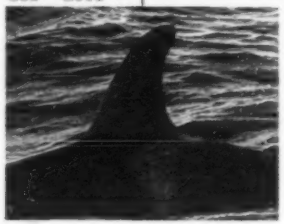
G41 ♀ 1987

G58 1996

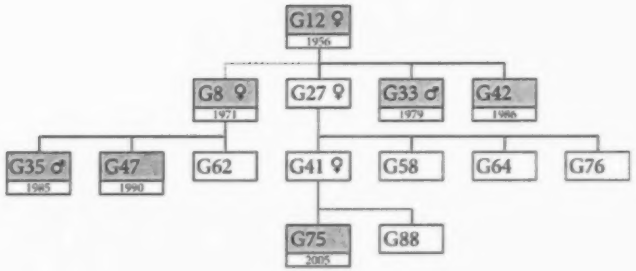
G64 2000

G76 2005

G88 2008

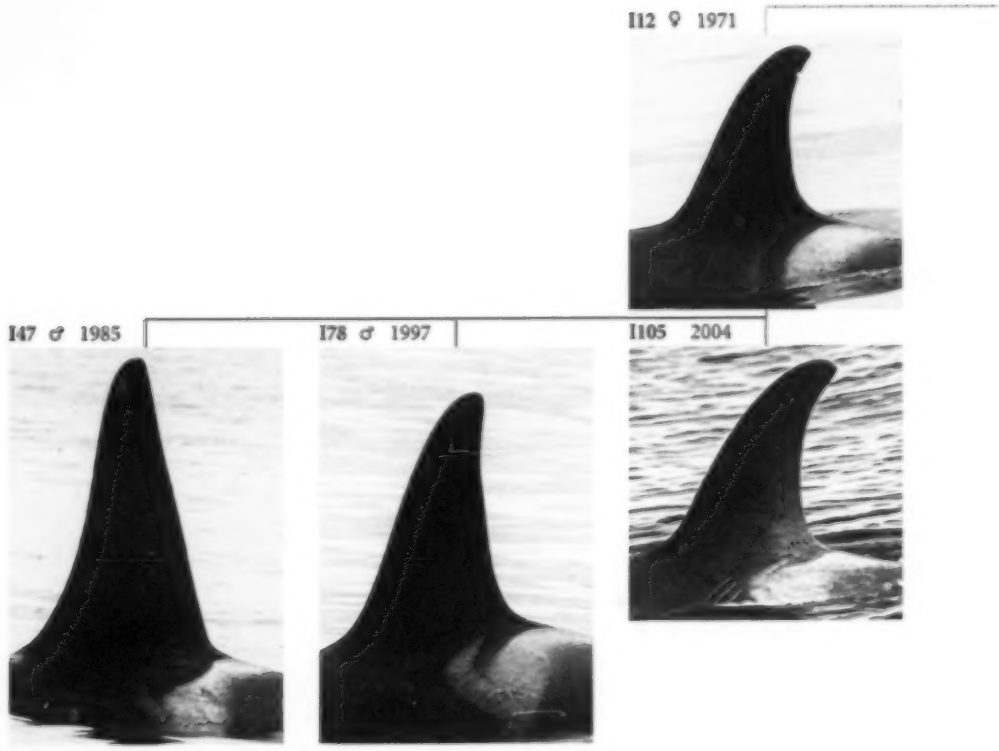


The orphan G62 is often seen travelling with the G2 matriline.



I11 Pod, G Clan

I11 Matriline



I11 Pod, G Clan
I11 Matriline

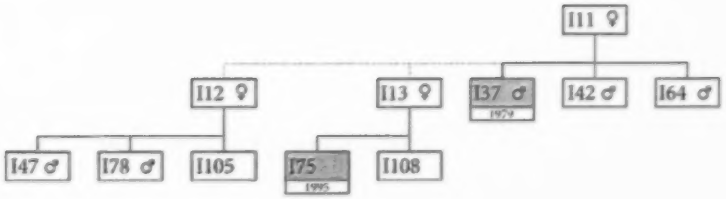
I11 ♀ 1955

I13 ♀ 1974

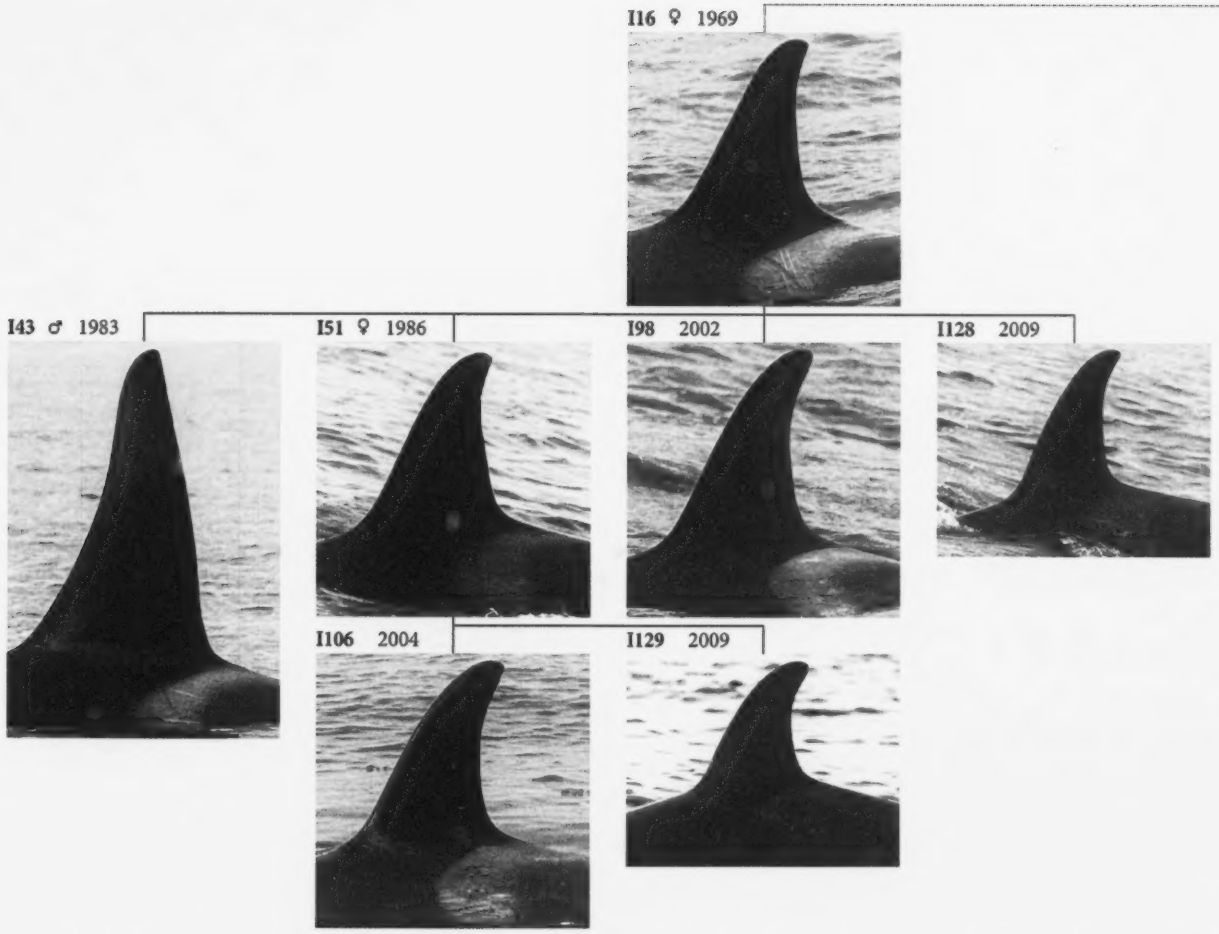
I42 ♂ 1983

I64 ♂ 1990

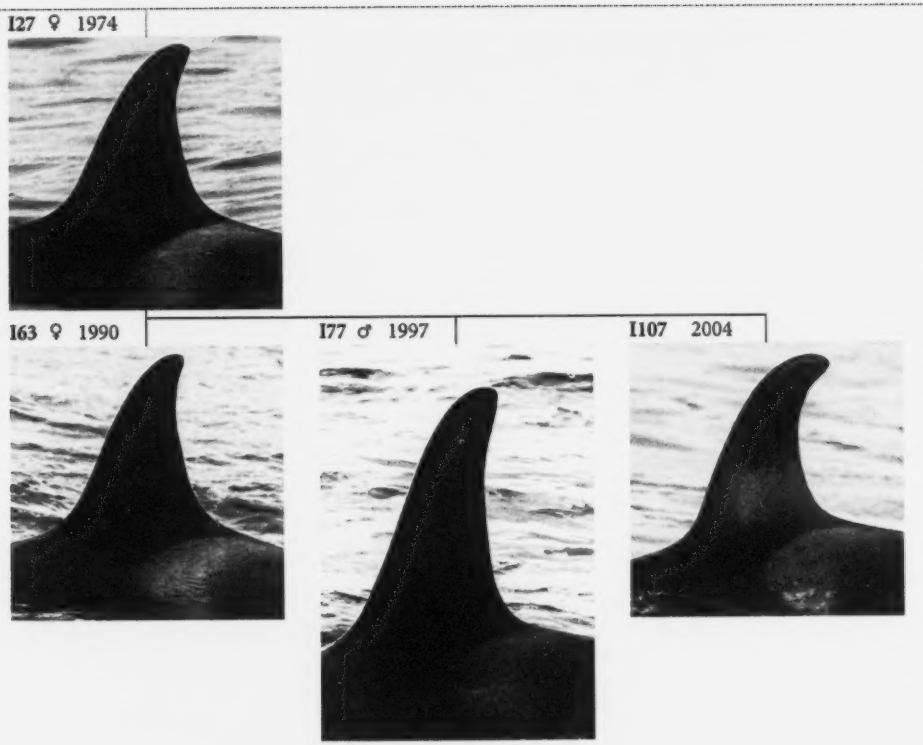
I108 2005

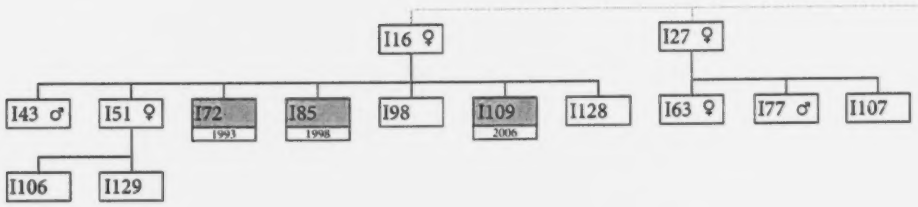


I11 Pod, G Clan
I15 Matriline

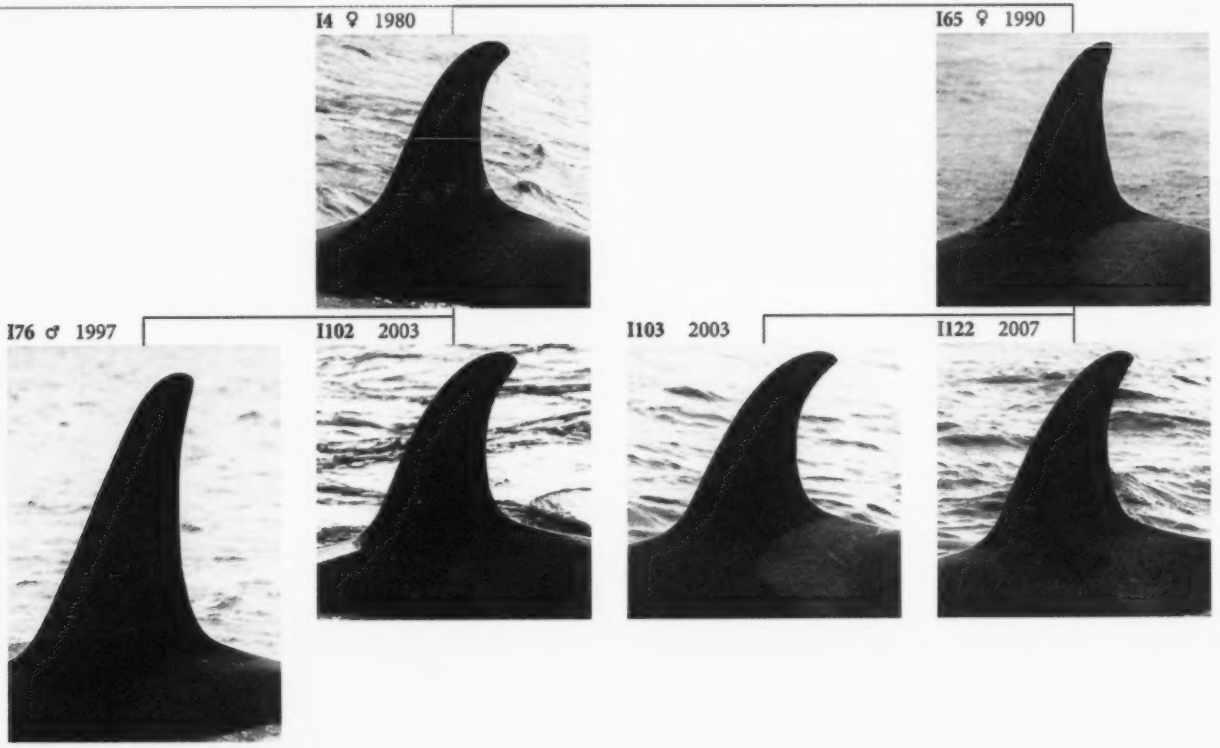


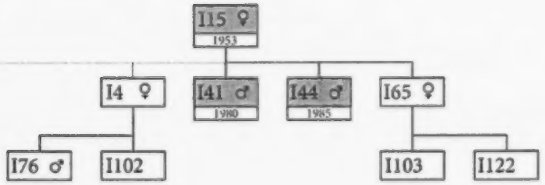
I11 Pod, G Clan
I15 Matriline





I11 Pod, G Clan
I15 Matriline





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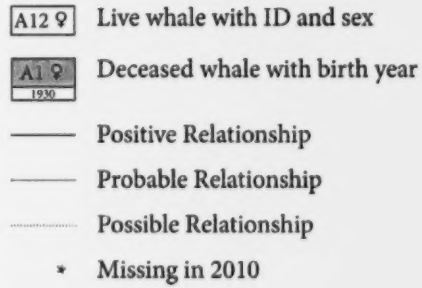
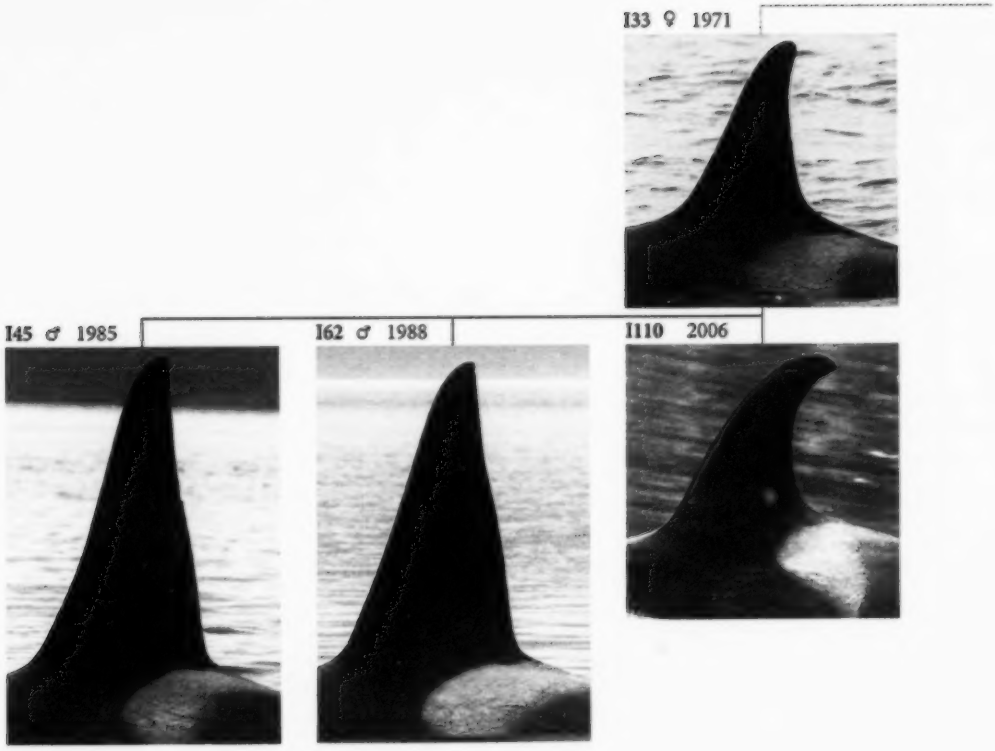
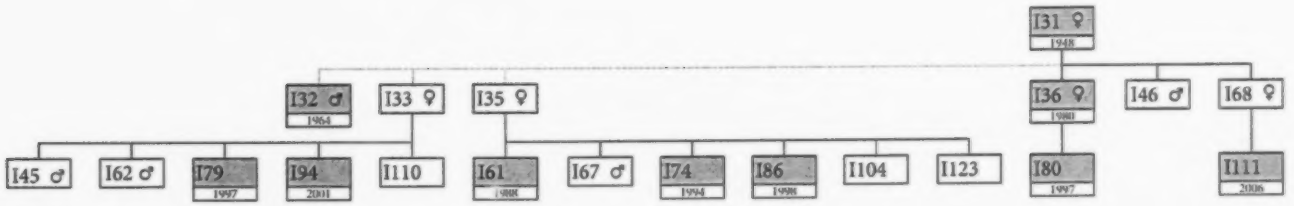
CATALOGUE KEY



I31 Pod, G Clan
I31 Matriline





I31 Pod, G Clan
I31 Matriline

I35 ♀ 1974

I46 ♂ 1985

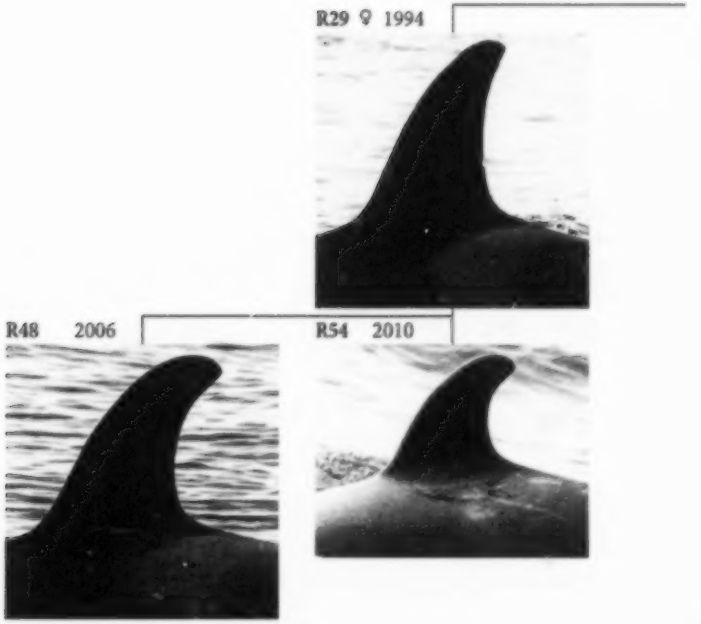
I68 ♀ 1991

I67 ♂ 1991

I104 2002

I123 2007

R1 Pod, R Clan
R5 Matriline



R1 Pod, R Clan

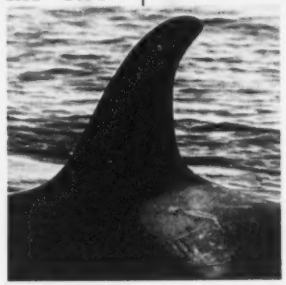
R5 Matriline

R22 ♀ 1984

R35 ♀ 1998

R39 2001

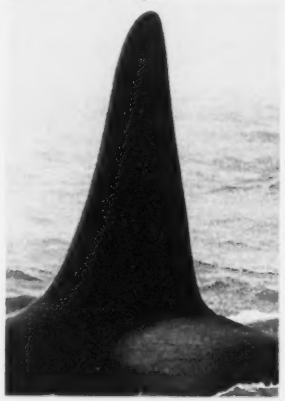
R44 2004

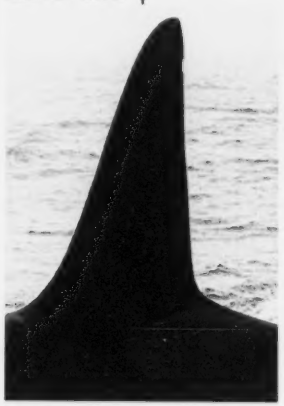


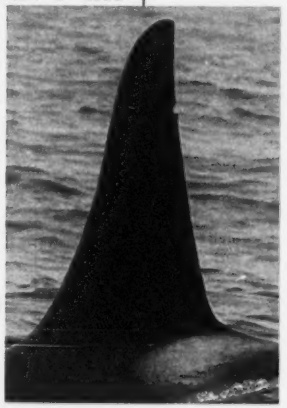
R50 2007

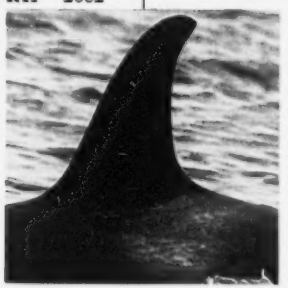
R55 2010

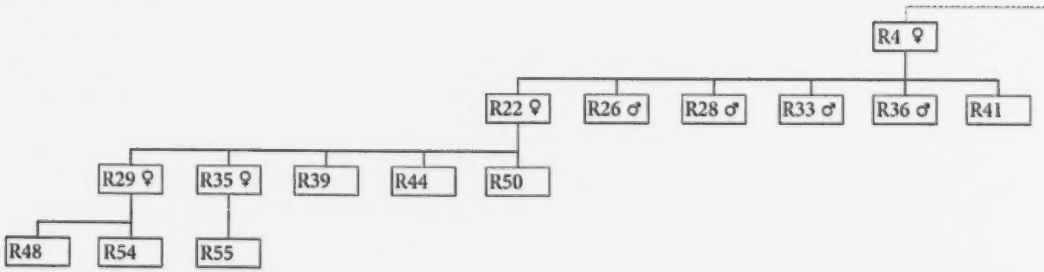
R1 Pod, R Clan
R5 Matriline



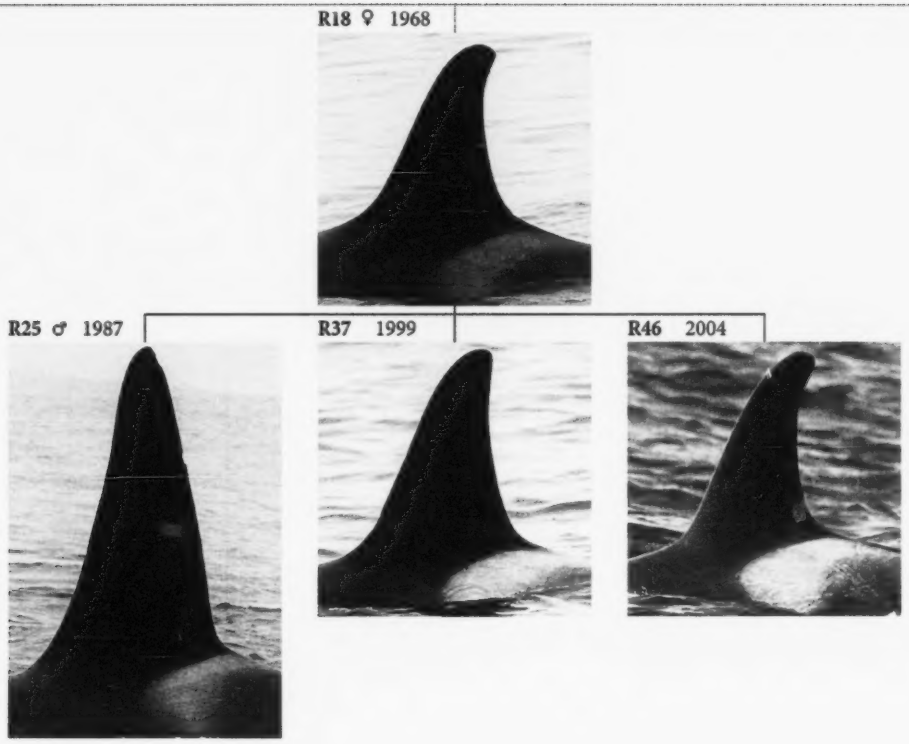


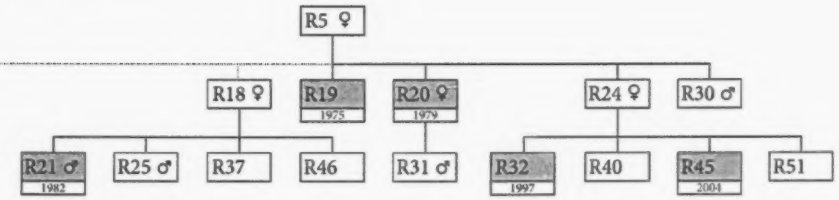






R1 Pod, R Clan
R5 Matriline

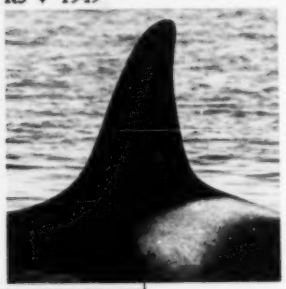




R1 Pod, R Clan

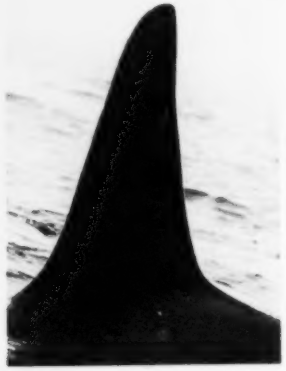
R5 Matriline

R5 ♀ 1949



R24 ♀ 1987

R30 ♂ 1994

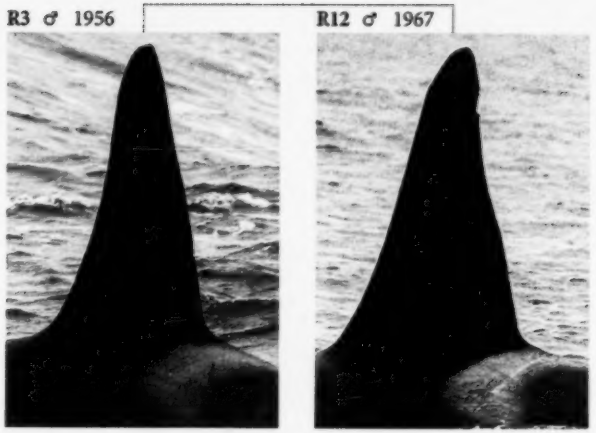


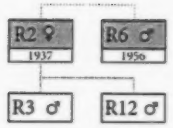
R31 ♂ 1997

R40 2001

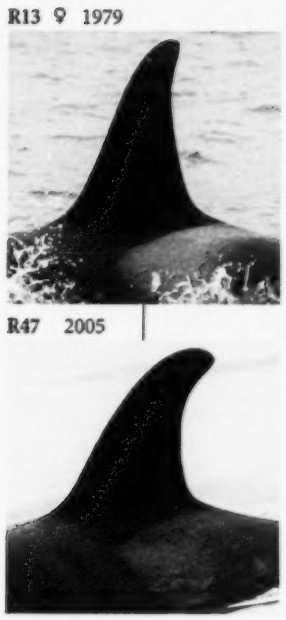
R51 2008

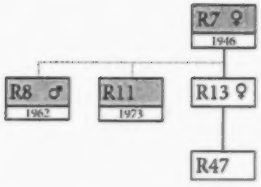
R1 Pod, R Clan
R2 Matriline





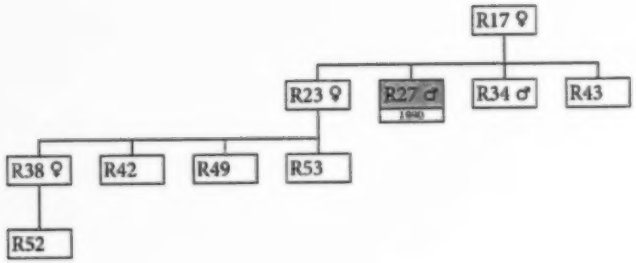
R1 Pod, R Clan
R13 Matriline

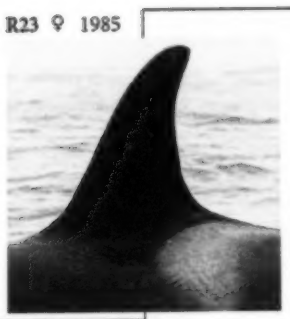


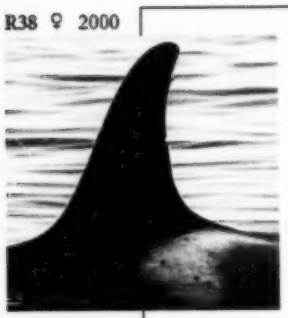


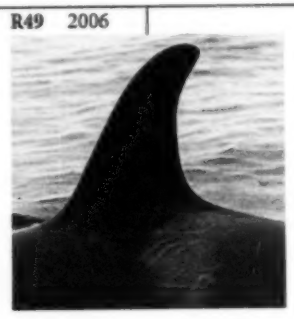
R1 Pod, R Clan

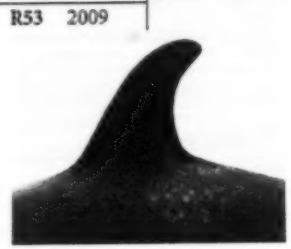
R17 Matriline











R1 Pod, R Clan
R17 Matriline

R17 ♀ 1971

R34 ♂ 1996

R43 2002

W1 Pod, R Clan
W3 Matriline

W3 ♀ 1935